REPORT NUMBER: TWG-MGA-2018-002

SIDE AIRBAG OUT-OF-POSITION INJURY
TECHNICAL WORKING GROUP

HYUNDAI MOTOR COMPANY
2018 Hyundai Santa Fe SE 5-Door SUV
NHTSA No.: M20184202TWG2

Test Date: September 25, 2018

Final Report Date: April 17, 2019

FINAL REPORT

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Date: _____

The results presented in this report relate only to the specified test items.

TECHNICAL REPORT DOCUMENTATION PAGE

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7. Author(s) Ben Fischer, Project Engineer		*8. Performing Organization Report No.* TWG-MGA-2018-002
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12. Sponsoring Agency Name and Address United States Department of Transportation National Highway Traffic Safety Administration Office of Crashworthiness Standards (NRM-110) 1200 New Jersey Ave, SE, Room W43-410 Washington, DC 20590		*13. Type of Report and Period Covered:* Final Test Report September 25, 2018 to April 17, 2019 *14. Sponsoring Agency Code* NRM-110
15. Supplementary Notes		

16. Abstract

A Side Airbag Out-of-Position Injury evaluation was conducted on the subject 2018 Hyundai Santa Fe SE 5-Door SUV in accordance with the specifications of the Side Airbag Out-of-Position Injury Technical Working Group Laboratory Test Procedure for the generation of consumer information. The test was conducted at MGA Research Corporation in Burlington, Wisconsin on September 25, 2018.

Injury Summary (SID-IIs Out-Of-Position)

HIC15	Maximum Chest Displacement (mm)	Maximum Chest Displacement Rate m/s)	Nij (NTF)	Nij (NTE)	Nij (NCF)	Nij (NCE)
19.383			0.10	0.15	0.33	0.68

17. Key Words Side Airbag Out-of-Position Technical Working Group OOP TWG SID-IIs		*18. Distribution Statement* Copies of this report are available from: National Highway Traffic Safety Administration Technical Information Services Division, NPO-411 1200 New Jersey Ave, SE Washington, DC 20590 e-mail: tis@nhtsa.dot.gov FAX: 202-493-2833	
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TABLE OF CONTENTS

SECTION 1
PURPOSE AND SUMMARY OF TEST

PURPOSE

The purpose of this test was to obtain data in a static out-of-position side air bag deployment. These data constitute part of the general consumer information collected by Alpha Technology Associate, Inc.

SUMMARY

The effects of both a curtain and torso airbag deployment in a 2018 Hyundai Santa Fe SE 5-Door SUV with an out-of-position SID-IIs Build Level D dummy were evaluated. The curtain and seat airbags were fired remotely. The test was performed by MGA Research Corporation on September 25, 2018. Pre- and post-test photographs of the vehicle and dummy can be found in Appendix A.

Three high-speed cameras (1000 fps) were used to document the side airbag deployment event. The following camera locations were used:

- Left Side Through Removed Driver Door
- Front Through Windshield
- Left Side ¾ View Through Windshield

One SID-IIs Build Level D dummy (Serial Number 304) was placed in the right front passenger seat lying on the seat per Section 3.3.5.3 according to dummy placement instructions specified in the Recommended Procedures for Evaluating Occupant Injury Risk from Deploying Side Airbags as prepared by the Side Airbag Out-of-Position Injury Technical Working Group (TWG).

The dummy was instrumented with the following instrumentation:

- Head Accelerometers
- Upper Neck Load Cell
- Lower Neck Load Cell

The 15 channels of data were recorded using an off board data acquisition system. Appendix B contains the dummy data traces.

The SID-IIs Build Level D dummy's visible contact points were as follows:

- Side curtain airbag to top and back of head
- Side torso/pelvis airbag to left side of torso and pelvis

The SID-IIs dummy was placed in the right front passenger seat facing toward the center of the vehicle with its arm against the seatback. The arm was rotated horizontally in the forward direction with respect to the dummy. The seat track was adjusted forward to minimize the vertical distance between the dummy's head and curtain airbag. The dummy's pelvis was slid outboard until the dummy's back contacted the door trim panel or armrest and the CG of the head was centered in the deployment trajectory of the airbag. The vertical plane through the centerline of the dummy's rib-stiffener and shoulder bolt was parallel to the centerline of the vehicle. Masking tape was wrapped around the dummy's neck bracket to hold the dummy in place.

The dummy's skullcap seam was taped with 4mm electrical tape to prevent the airbag from getting caught in the seam. The dummy's head skin was cleaned with alcohol and dusted with baby powder to achieve acceptable frictional characteristics.

This orientation complies with Section 3.3.5.3 of the TWG Recommended Procedures for Evaluating Occupant Injury Risk from Deploying Side Airbags as defined by Lund, et al and the Technical Working Group First Revision dated July, 2003.

SECTION 2
OCCUPANT AND VEHICLE INFORMATION / DATA SHEETS

DATA SHEET NO. 1

TEST SUMMARY

	Test Data	Description
Seating Position	P2	Right Front Seating Position
Test	3.3.5.3*	Inboard-Facing SID-IIs
Curtain Airbag	Roof-Rail Mounted	Side Curtain Airbag
Torso Airbag	Seat Mounted	Side Torso/Pelvis Airbag
ATD Type/Serial No.	SID-IIs Build Level D / 304	5th Percentile Adult Female

*Procedure as defined by Lund, et al and the Technical Working Group dated July, 2003

Number of Data Channels	15
Number of Airbag Channels	4
Number of High-Speed Video	3

Visible Dummy Contact Points	
Head Contact	Side curtain airbag to top and back of head
Left Shoulder Contact	None
Left Torso Contact	Side torso/pelvis airbag to torso
Left Pelvis Contact	Side torso/pelvis airbag to pelvis

DATA SHEET NO. 2

TEST VEHICLE INFORMATION

Please note that this vehicle had previously been tested in an NCAP Side Impact on November 17, 2017.

TEST VEHICLE INFORMATION

Manufacturer	Hyundai
Model	Santa Fe SE
Body Style	5-Door SUV
NHTSA No.	M20184202
VIN	KM8SM4HF5JU282445
Color	Circuit Silver
Delivery Date	10/2/2017
Odometer Reading	173 miles
Dealer	Boucher Fleet Group
Transmission	Automatic
Final Drive	FWD
Number of Cylinders	6
Engine Displacement	3.3 L
Engine Placement	Lateral
Automatic Door Lock (ADL)	Yes
Owner's Manual Details Instructions on Disabling ADLs	No
Bucket Seats	Yes

TEST VEHICLE OPTIONS

Driver Front Airbag	Yes
Driver Side Curtain Airbag	Yes
Driver Side Torso Airbag	No
Driver Side Torso/Pelvis Airbag	Yes
Rear Pass. Side Curtain Airbag	Yes
Rear Pass. Side Torso Airbag	No
Rear Pass. Side Torso/Pelvis Airbag	No
Force Limiter	Yes
Pretensioner	Yes
Power Steering	Yes
Power Door Locks	Yes
Tilt Wheel	Yes
Air Conditioning	Yes
Anti-lock Brakes	Yes
Traction Control	Yes
All-Wheel Drive	No
Power Seats	Yes

DATA FROM CERTIFICATION LABEL

Manufactured By	HYUNDAI MOTOR COMPANY
Date of Manufacture	05/17

GVWR (kg)	2500
GAWR Front (kg)	1390
GAWR Rear (kg)	1395

Measured Parameter	Front	Rear	Third	Total
Type of Seats	Bucket	Split Bench	Split Bench	
Number of Occupants	2	3	2	7
Capacity Wt. (VCW) (kg)				588
Cargo Wt. (RCLW) (kg)				112

DATA SHEET NO. 3

DUMMY POSITIONING IN VEHICLE

Measurement		Value
Seat Position (from forward-most)		190 of 240 mm
Seat Height Position		Fixed
Placed in Position No. 2		-
Seat Back Angle (at outboard headrest post)	SA (°)	-18.4
Top of Curtain Airbag Module to Head/Neck Junction	AN (mm)	420
Top of Seat Airbag Module to Head/Neck Junction	AN (mm)	140
Head CG to Window	HD (mm)	158
Head to Seat Back Centerline	HSC (mm)	85
ATD Back to Door Trim	CD (mm)	0
Chest to Seatback	CS (mm)	240
Right Arm to Seat Back Centerline	RACL (mm)	-
Left Arm to Seat Back Centerline	LACL (mm)	230
Right Arm to Door Panel	RA (mm)	-
Left Arm to Door Panel	LA (mm)	30
Knee to Knee	KK (mm)	102
Toe to Toe	TT (mm)	80
Right Knee to Seat Cushion Centerline	KSCR (mm)	208
Left Knee to Seat Cushion Centerline	KSCL (mm)	197
Right Toe to Seat Cushion Centerline	TSCR (mm)	575
Left Toe to Seat Cushion Centerline	TSCL (mm)	585
Nose to Front Seatback	ND (mm)	660
Nose to Seatback	NS (mm)	254
Top of Head to Headliner	HH (mm)	110

DATA SHEET NO. 4

DUMMY INJURY CRITERIA VALUES

NHTSA No. M20184202TWG2

		Position No. 2			
DESCRIPTION	UNIT	MAXIMUM	TIME (ms)	MINIMUM	TIME (ms)
Head X	g	20.2	32.7	-5.1	157.5
Head Y	g	8.5	32.3	-7.7	18.3
Head Z	g	16.5	24.5	-10.5	17.7
Head Resultant	g	24.4	31.9		
Upper Neck Fx	N	132.4	20.8	-166.6	34.7
Upper Neck Fy	N	413.5	37.8	-91.4	156.7
Upper Neck Fz	N	233.5	123.2	-918.5	17.3
Upper Neck F Resultant	N	935.3	17.3		
Upper Neck Mx	Nm	13.9	76.1	-24.8	15.5
Upper Neck My	Nm	19.0	20.9	-33.4	42.1
Upper Neck Mz	Nm	7.4	25.6	-9.0	91.2
Upper Neck M Resultant	Nm	34.8	42.0		
Lower Neck Fx	N	482.6	17.2	-344.2	52.0
Lower Neck Fy	N	506.5	13.8	-79.8	153.9
Lower Neck Fz	N	318.7	123.4	-1071.0	18.0
Lower Neck F Resultant	N	1193.2	18.0		
Lower Neck Mx	Nm	47.3	41.6	-19.5	155.8
Lower Neck My	Nm	43.1	38.9	-23.7	24.6
Lower Neck Mz	Nm	21.1	13.9	-12.9	71.8
Lower Neck M Resultant	Nm	62.8	39.4		

DATA SHEET NO. 4 (continued)

DUMMY INJURY CRITERIA VALUES

NHTSA No. M20184202TWG2

Head Injury Summary (SID-IIs Out-Of-Position)

	HEAD INJURY CRITERIA (HIC)					
	HIC15			HIC36		
ATD position	HIC	T^1 (msec)	T^2 (msec)	HIC	T^1 (msec)	T^2 (msec)
No. 304 Right Front	19.383	23.2	38.2	28.246	14.1	46.9

Neck Injury Summary (SID-IIs Out-Of-Position)

	Nij	Time (msec)	Z Force (N) (CFC 600)	X Force (N) (CFC 600)	Y Moment (N-m) (CFC 600)
Ntf	0.10	139.8	147.6	-98.0	7.9
Nte	0.15	71.7	13.8	86.6	-7.4
Ncf	0.33	18.5	-880.1	101.8	18.0
Nce	0.68	39.6	-745.7	-131.5	31.9
Peak Tension (CFC1000)		**233.5 N**	**Peak Compression (CFC 1000)**		**-918.5 N**

Critical Values

Nij Intercepts				Peak Limits	
Tension (CVt)	3880 N	Extension (mCVe)	61 N-m	Tension	2070 N
Compression (CVc)	3880 N	Flexion (mCVf)	155 N-m	Compression	2520 N
Condyle Offset	0.01778 m				

APPENDIX A

PHOTOGRAPHS

TABLE OF PHOTOGRAPHS

Photo No. 001 - Right Three-Quarter Front View of Vehicle, As Received

Photo No. 002 - Vehicle Certification Placard

Photo No. 003 - Pre-Test Vehicle Left Side View

Photo No. 004 - Post-Test Vehicle Left Side View

Photo No. 005 - Pre-Test SID-IIs Left Side View

Photo No. 006 - Post-Test SID-IIs Left Side View

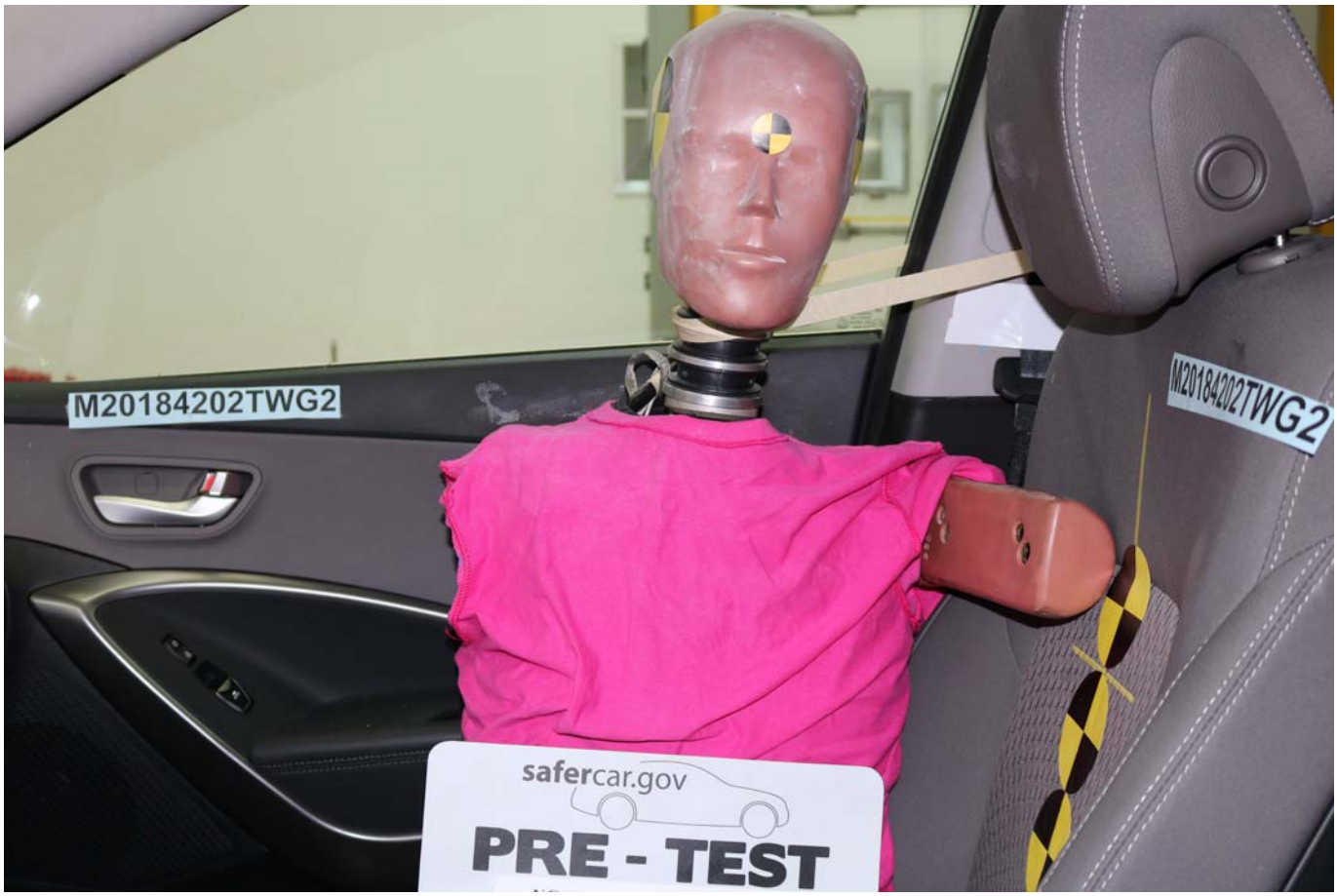


Photo No. 007 - Pre-Test SID-IIs Left Side Close-Up View

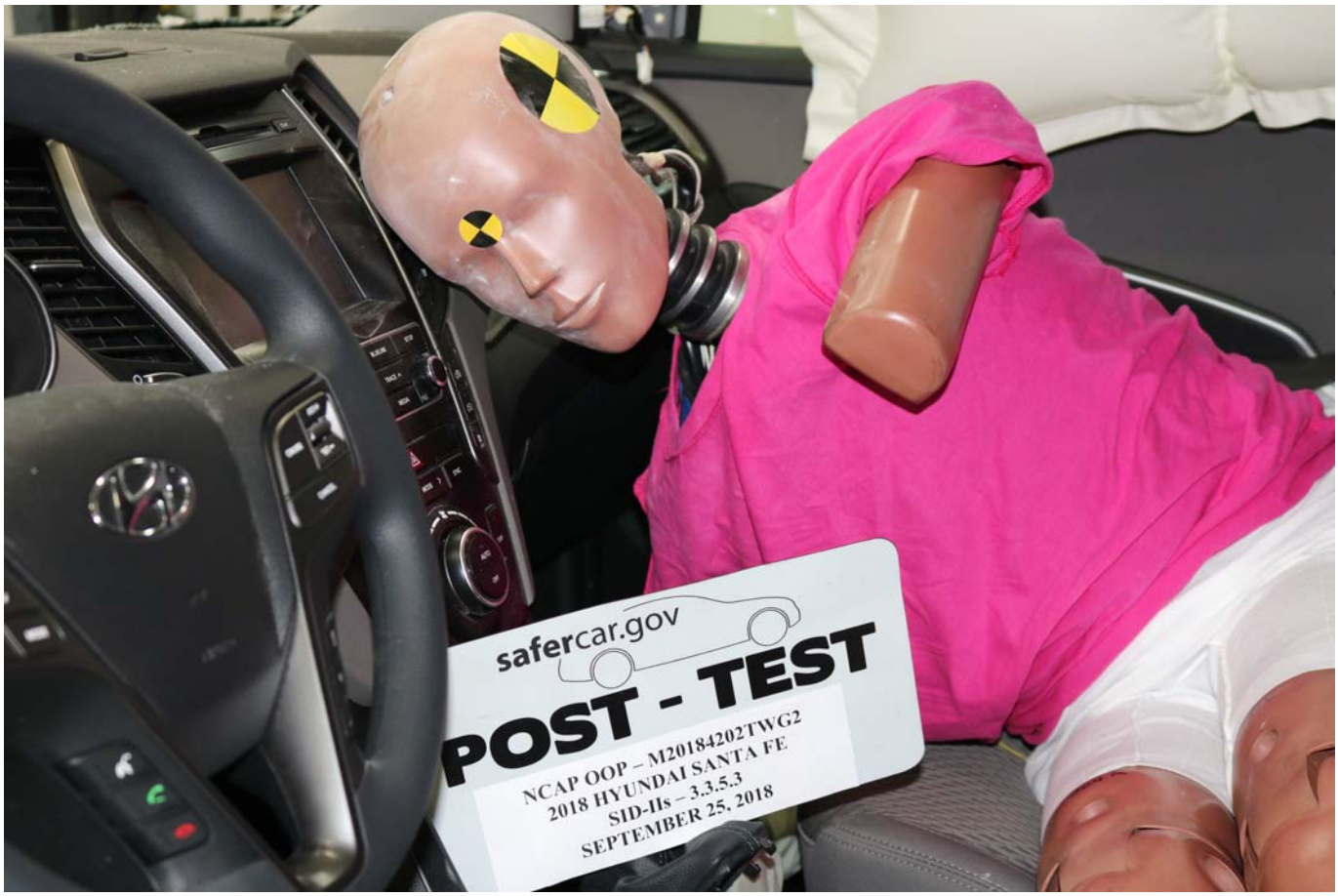


Photo No. 008 - Post-Test SID-IIs Left Side Close-Up View

Photo No. 009 - Pre-Test SID-IIs Left Three-Quarter Front View

Photo No. 010 - Post-Test SID-IIs Left Three-Quarter Front View

Photo No. 011 - Pre-Test SID-IIs Left Three-Quarter Front Close-Up View

Photo No. 012 - Post-Test SID-IIs Left Three-Quarter Front Close-Up View

Photo No. 013 - Pre-Test SID-IIs Front View

Photo No. 014 - Post-Test SID-IIs Front View

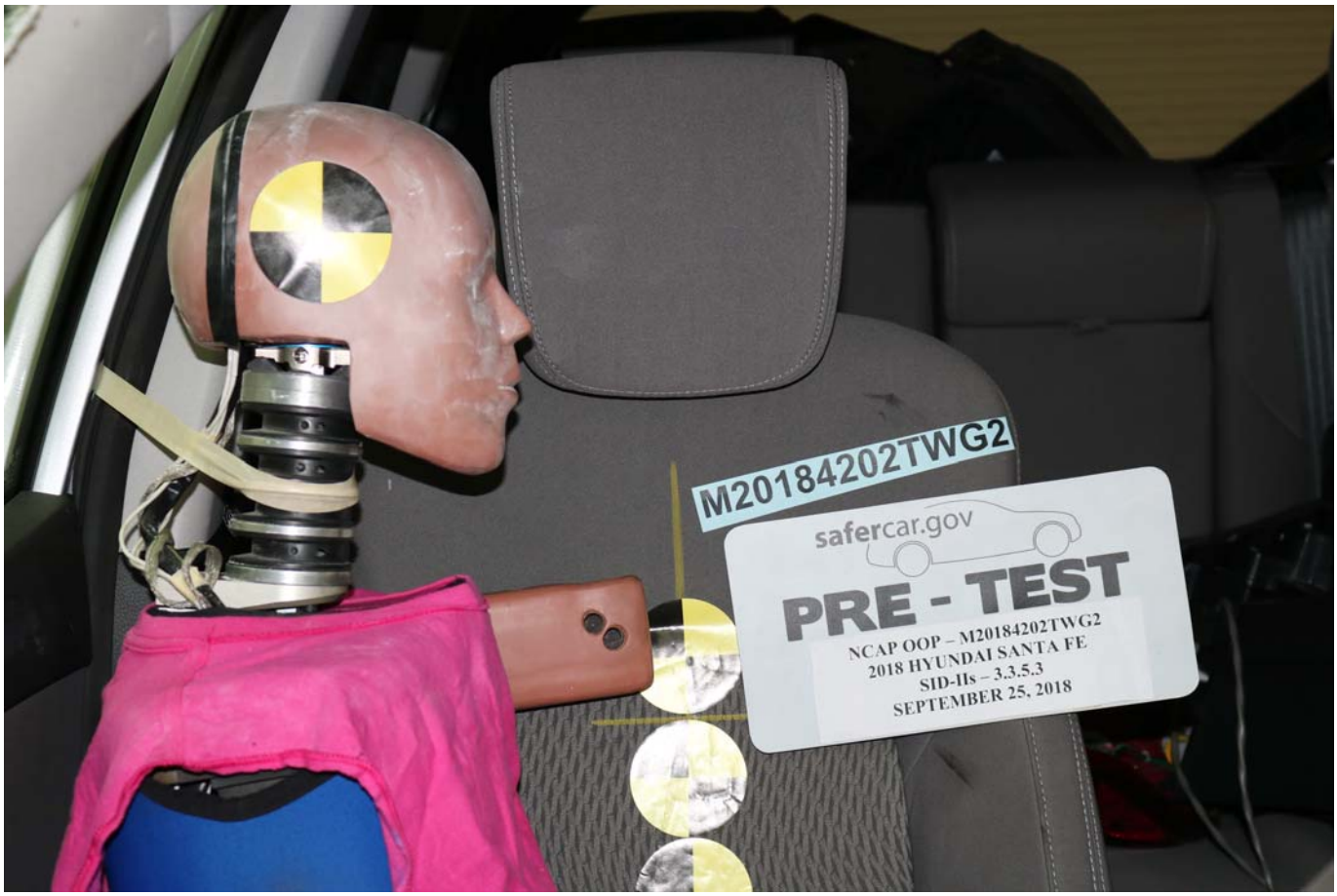


Photo No. 015 - Pre-Test SID-IIs Front Close-Up View

Photo No. 016 - Post-Test SID-IIs Front Close-Up View

Photo No. 017 - Pre-Test SID-IIs Right Three-Quarter Front View

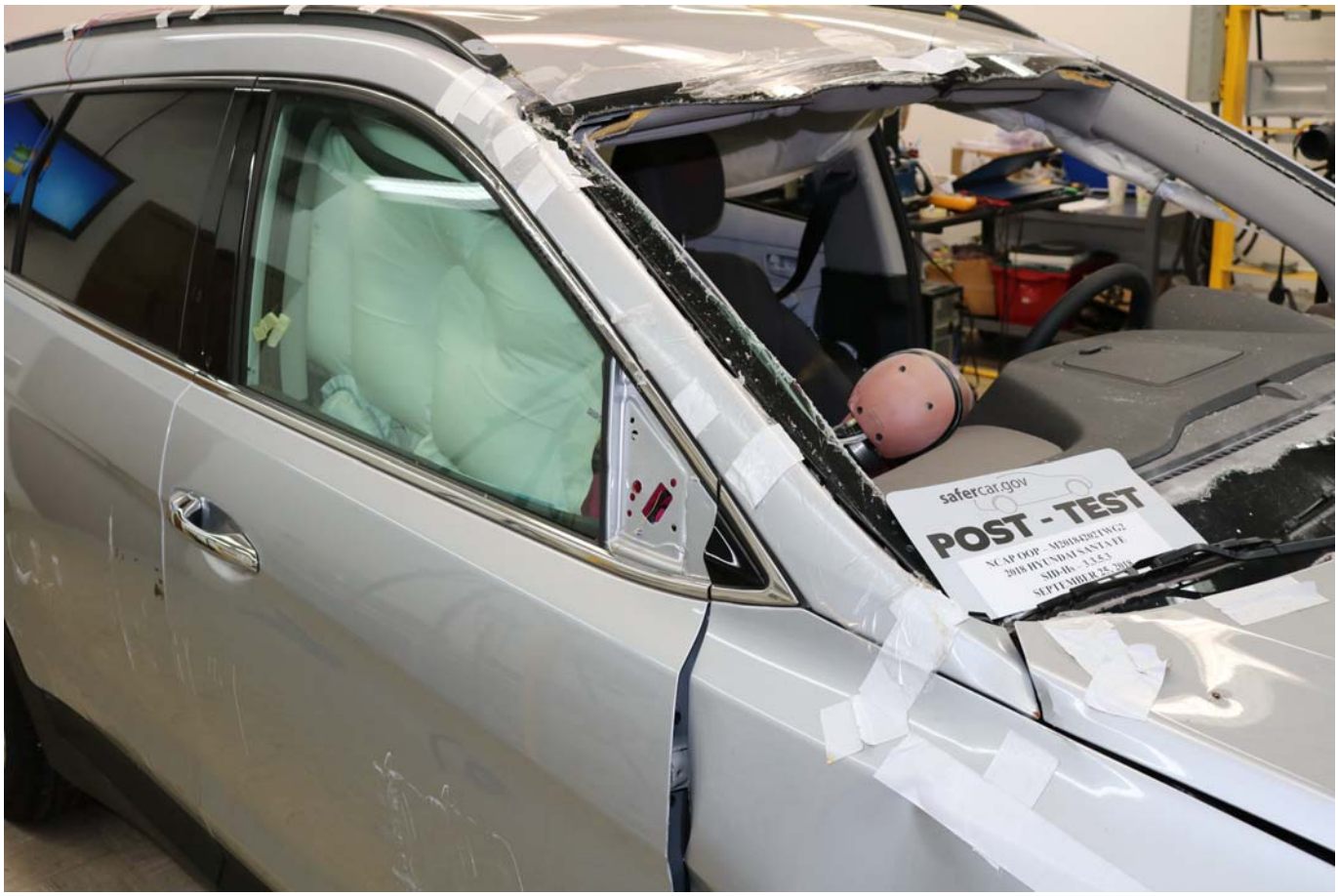


Photo No. 018 - Post-Test SID-IIs Right Three-Quarter Front View

Photo No. 019 - Pre-Test SID-IIs Right Side View

Photo No. 020 - Post-Test SID-IIs Right Side View

Photo No. 021 - Post-Test SID-IIs Right Side View (Door Open)

Photo No. 022 - Post-Test Curtain Airbag Left Side View

Photo No. 023 - Post-Test Curtain Airbag Left Three-Quarter Front View

Photo No. 024 - Post-Test Curtain Airbag Front View

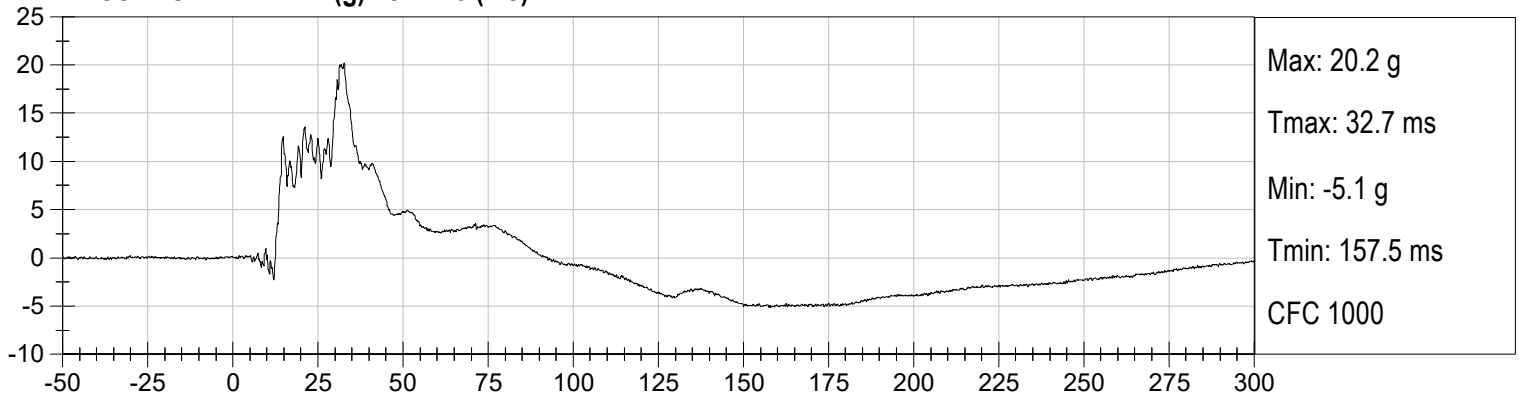
Photo No. 025 - Post-Test Curtain Airbag Right Side View (Door Open)

APPENDIX B

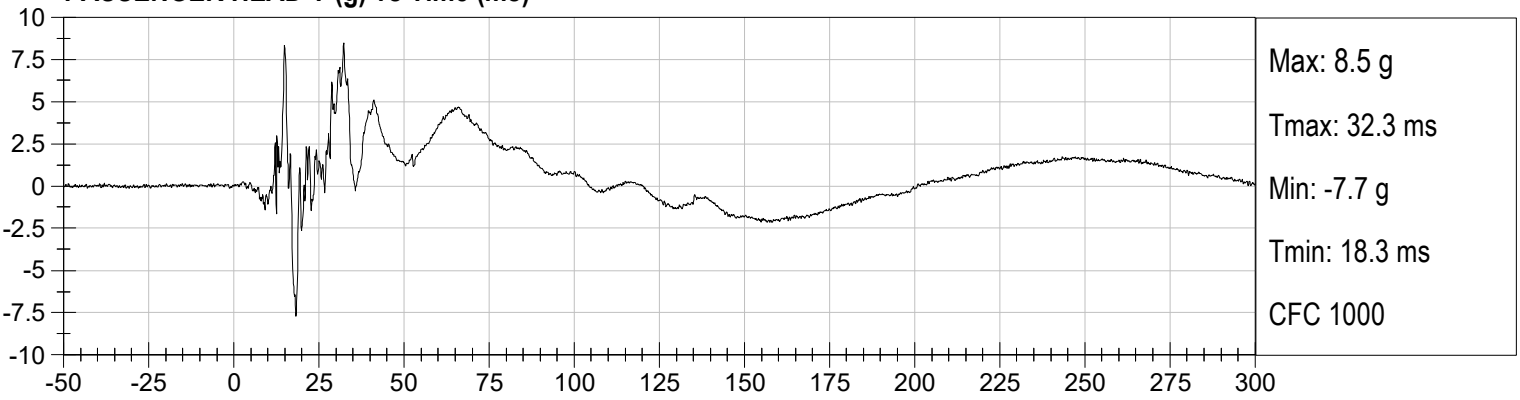
DUMMY RESPONSE DATA TRACES

TABLE OF DATA PLOTS

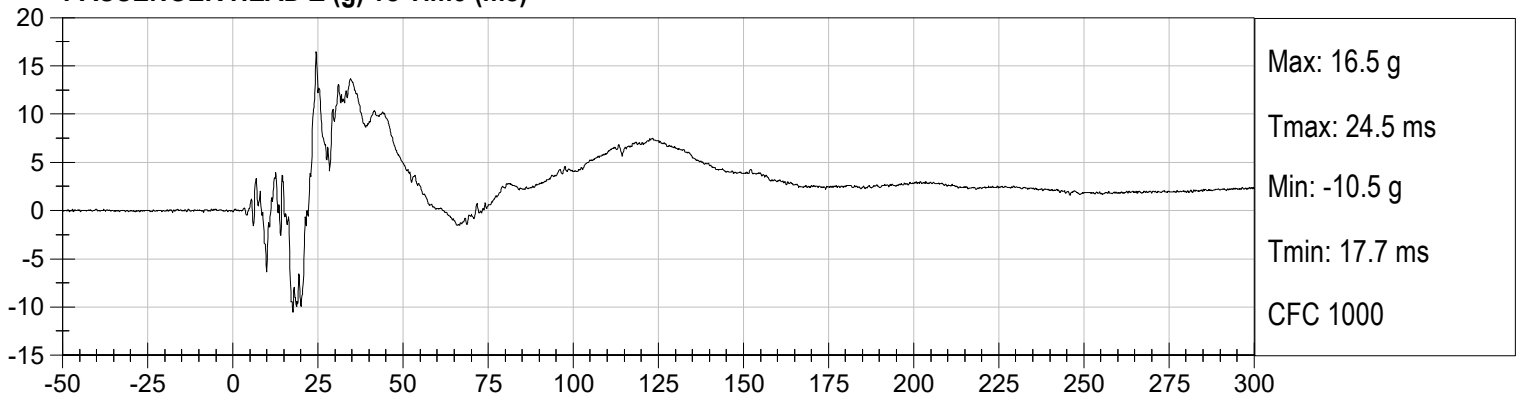
PASSENGER HEAD X (g) vs Time (ms)



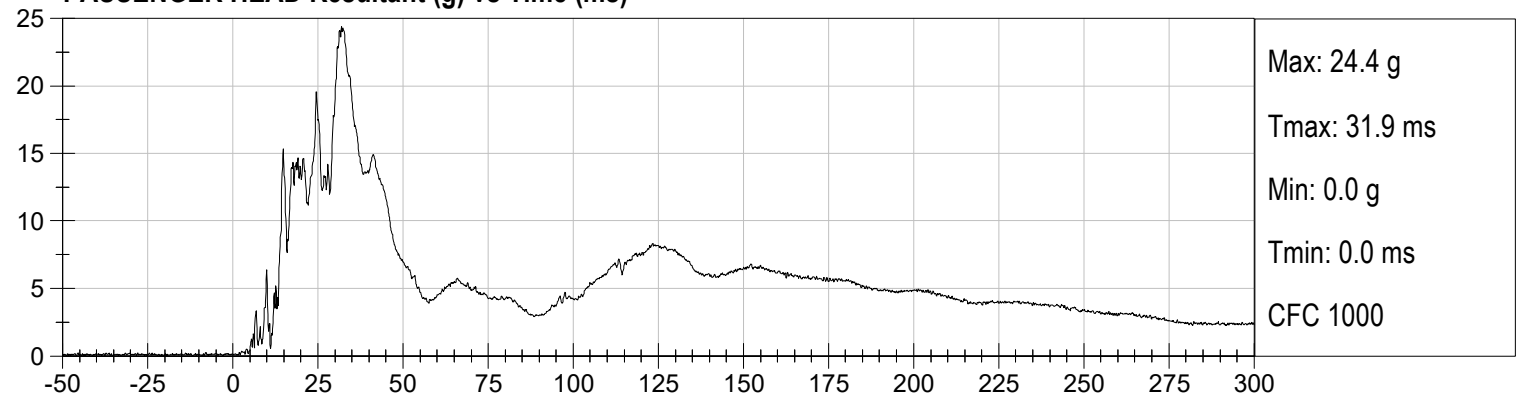
PASSENGER HEAD Y (g) vs Time (ms)



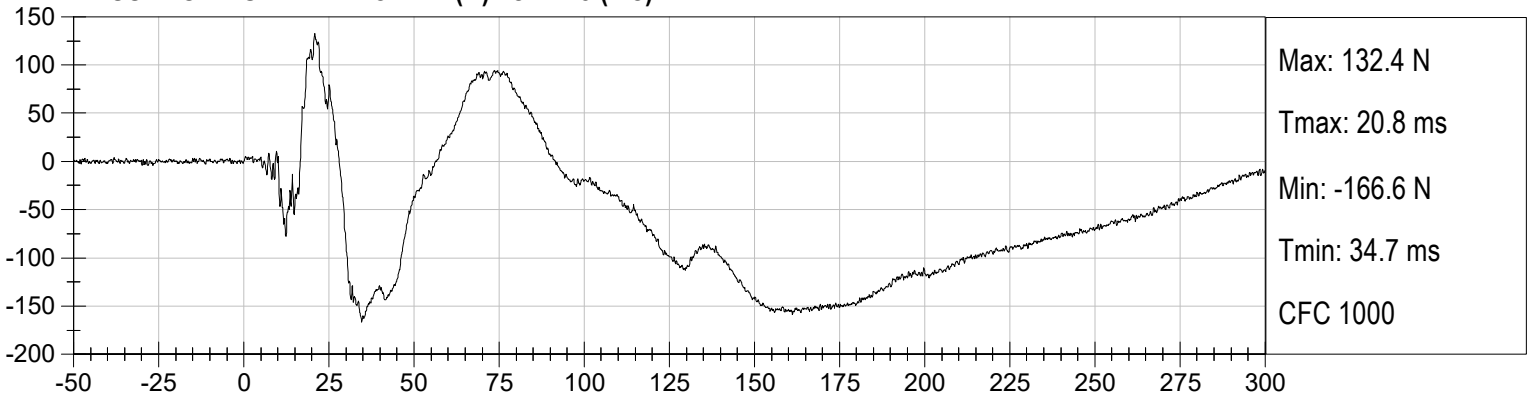
PASSENGER HEAD Z (g) vs Time (ms)



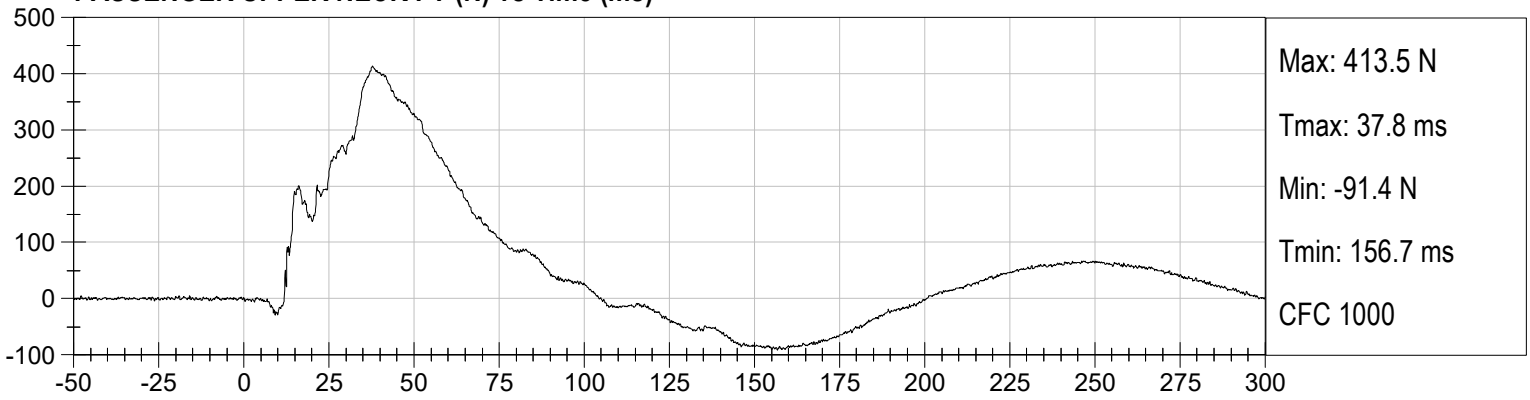
PASSENGER HEAD Resultant (g) vs Time (ms)



PASSENGER UPPER NECK FX (N) vs Time (ms)



PASSENGER UPPER NECK FY (N) vs Time (ms)



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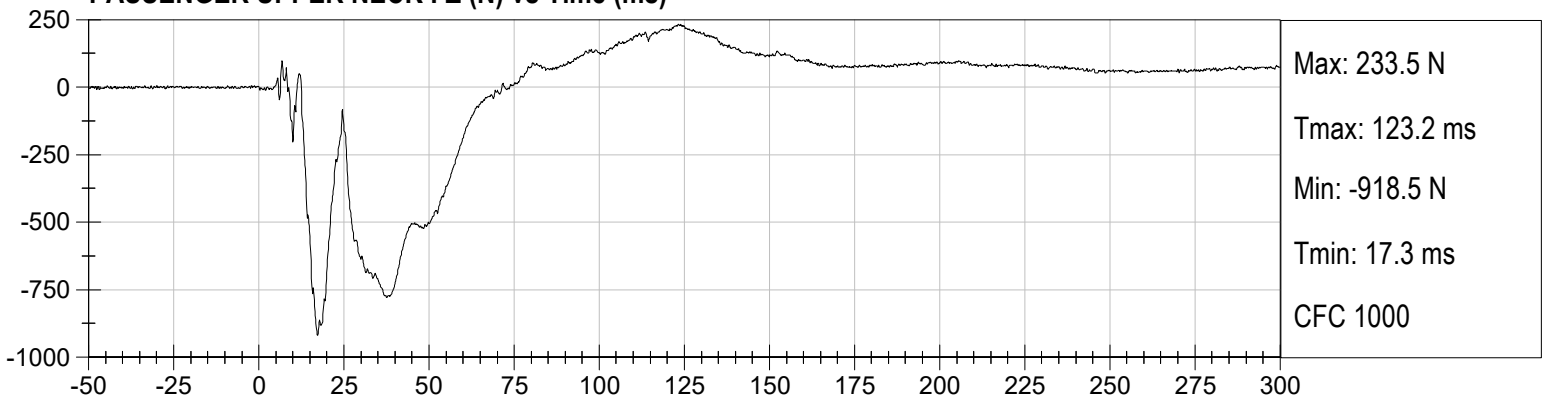
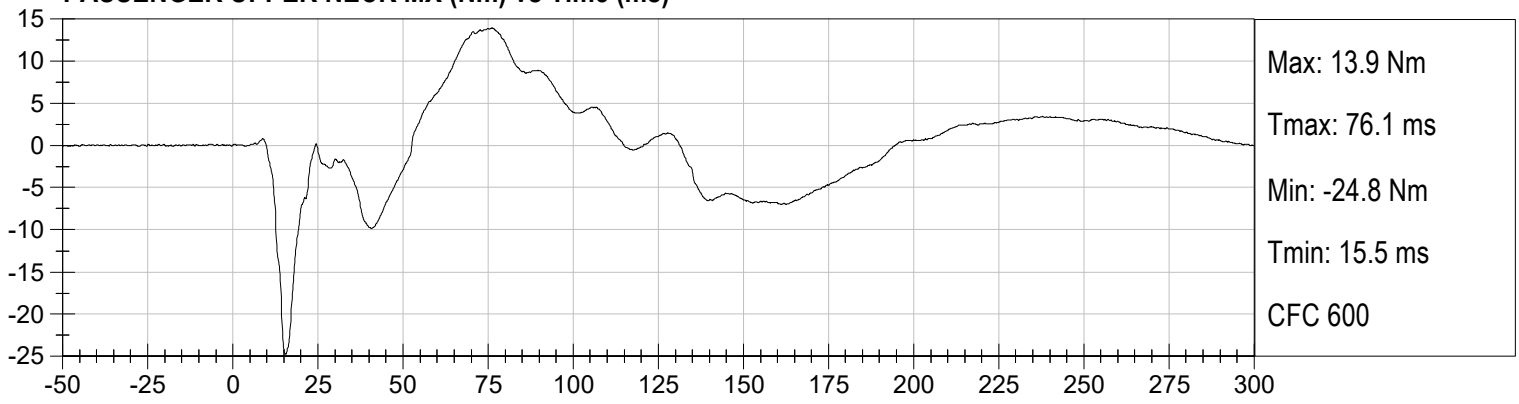
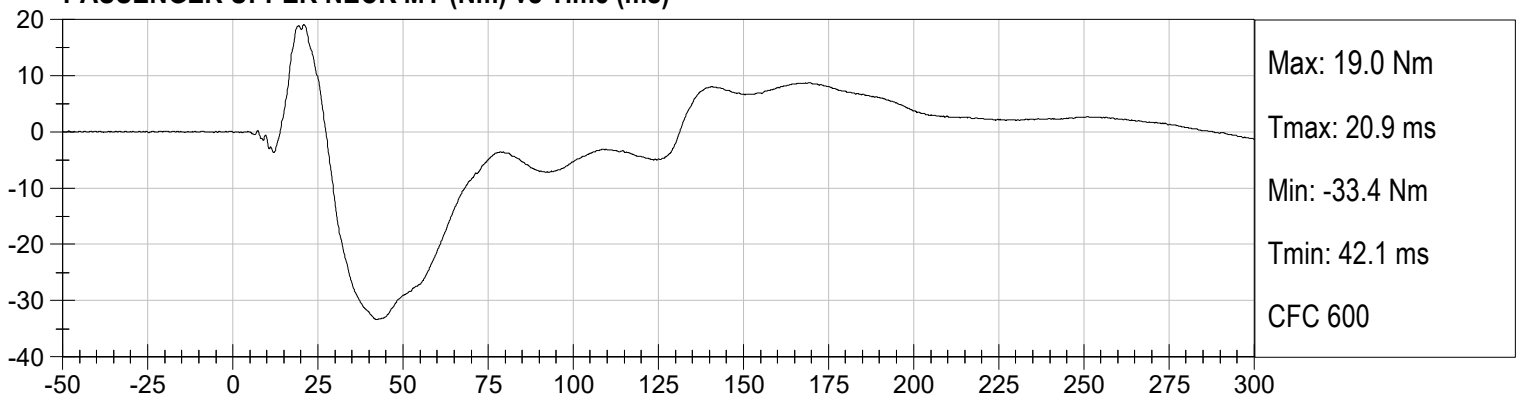


PASSENGER UPPER NECK FResultant (N) vs Time (ms)

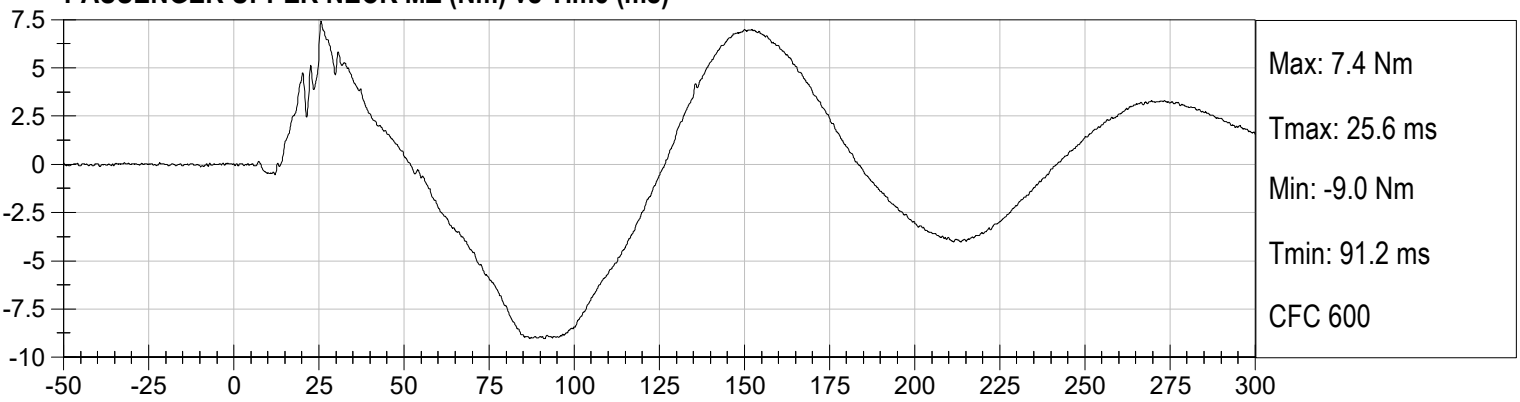
PASSENGER UPPER NECK MX (Nm) vs Time (ms)



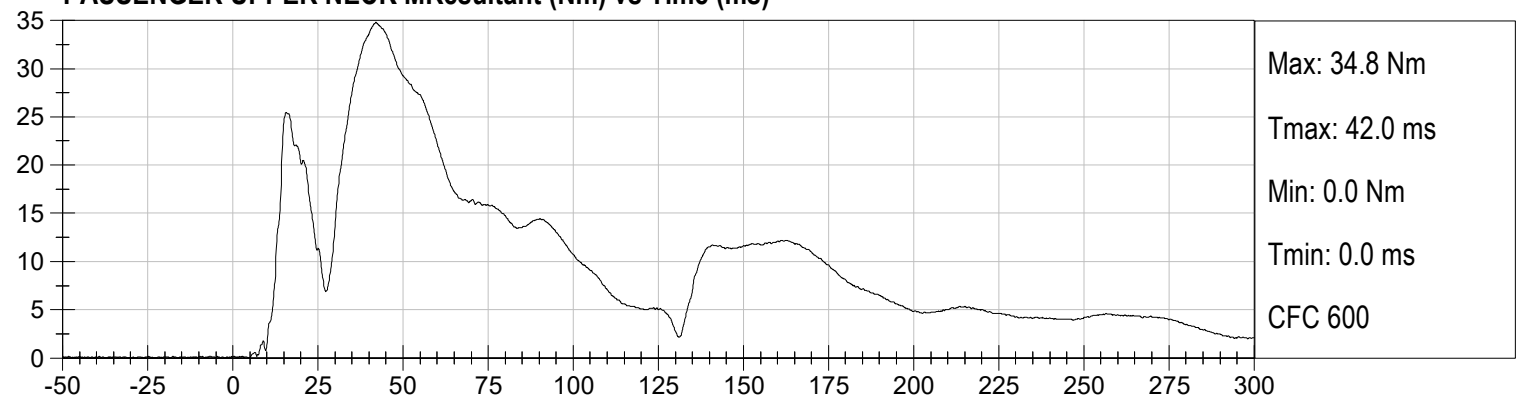
PASSENGER UPPER NECK MY (Nm) vs Time (ms)



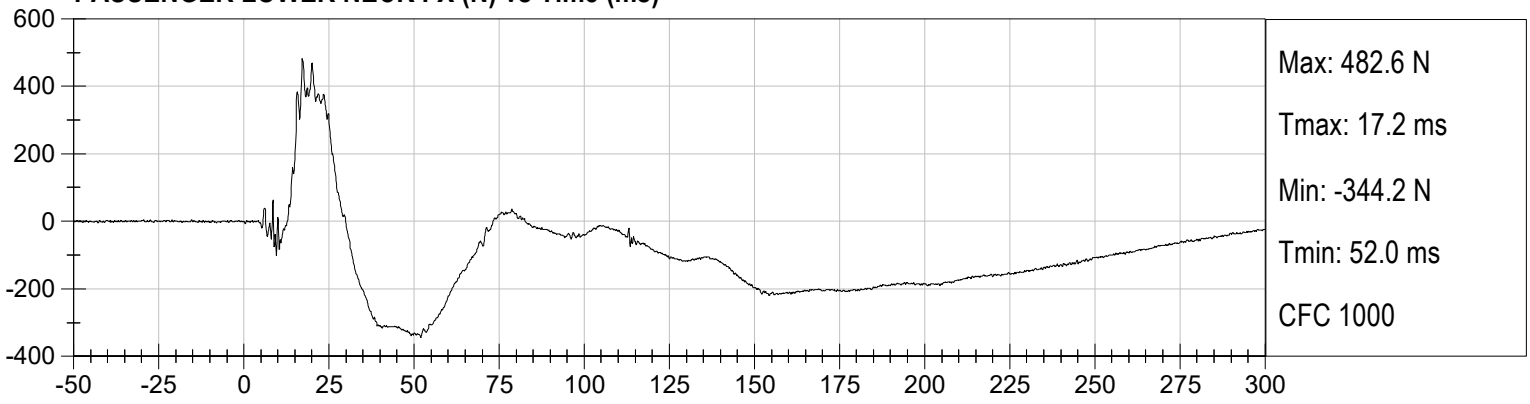
PASSENGER UPPER NECK MZ (Nm) vs Time (ms)



PASSENGER UPPER NECK MResultant (Nm) vs Time (ms)

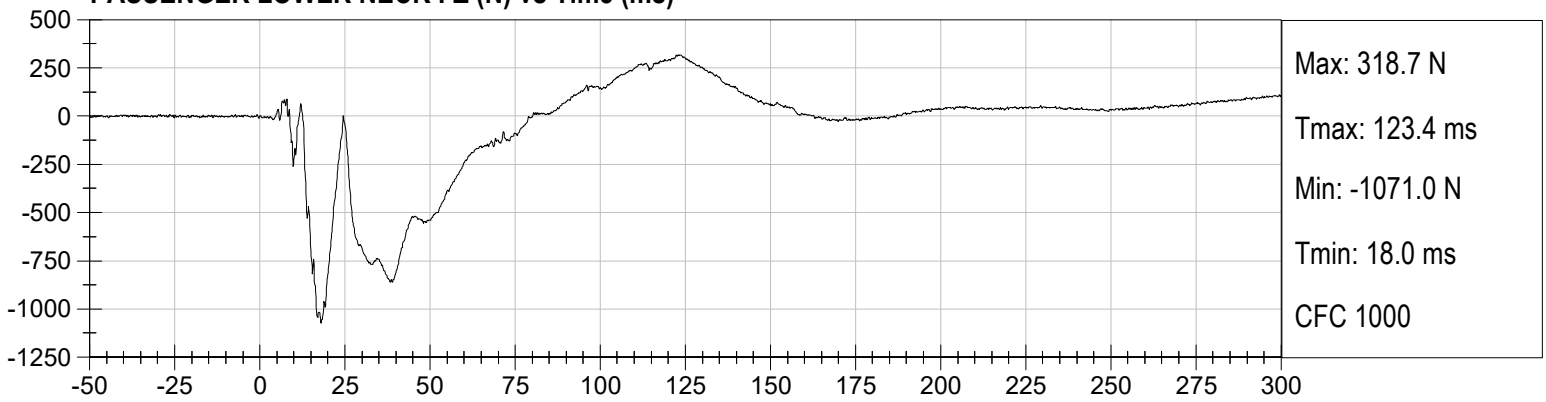


PASSENGER LOWER NECK FX (N) vs Time (ms)

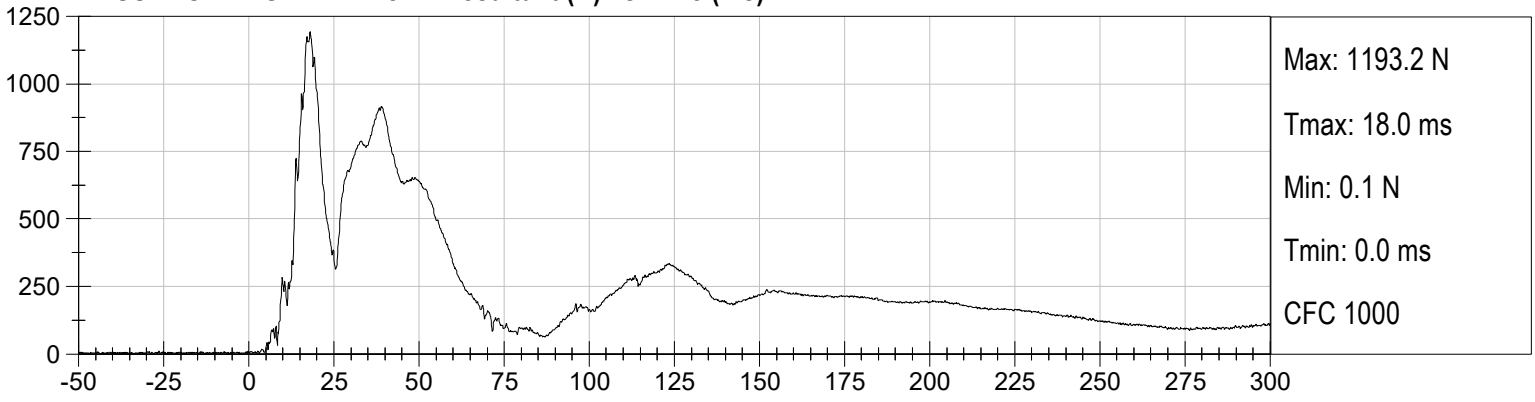


PASSENGER LOWER NECK FY (N) vs Time (ms)

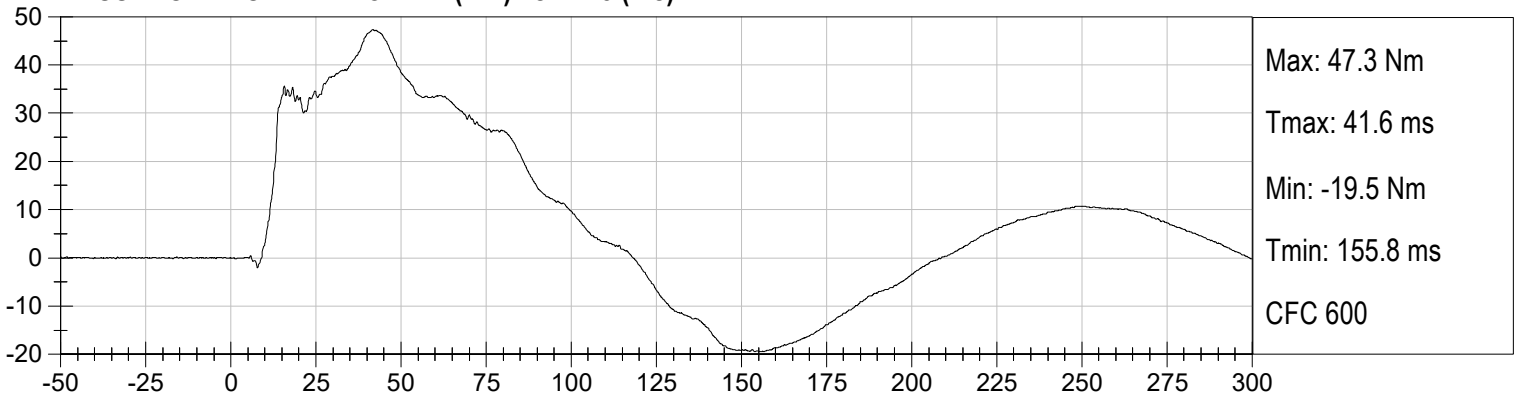
PASSENGER LOWER NECK FZ (N) vs Time (ms)



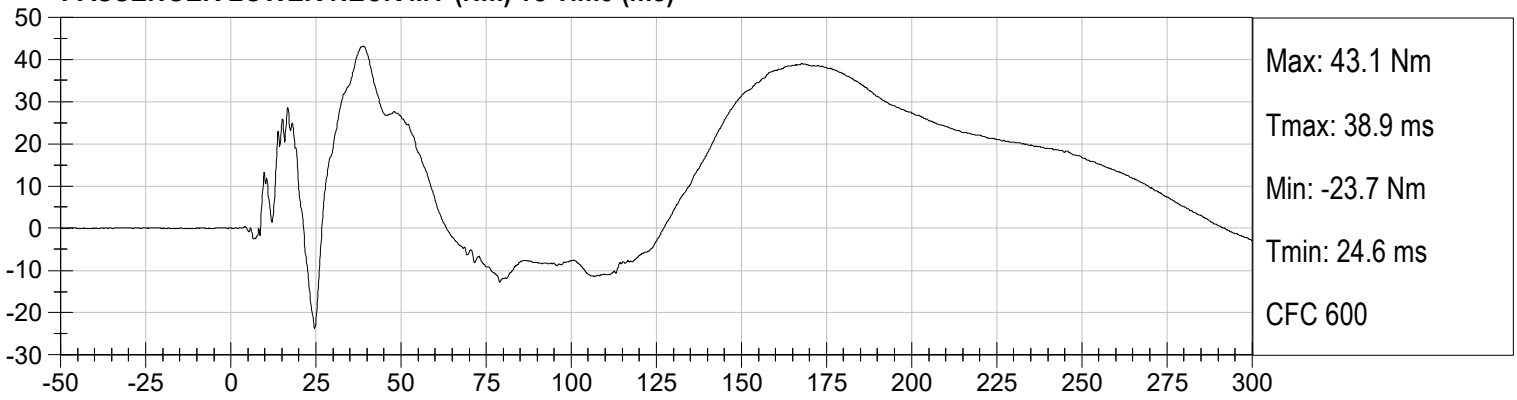
PASSENGER LOWER NECK FResultant (N) vs Time (ms)



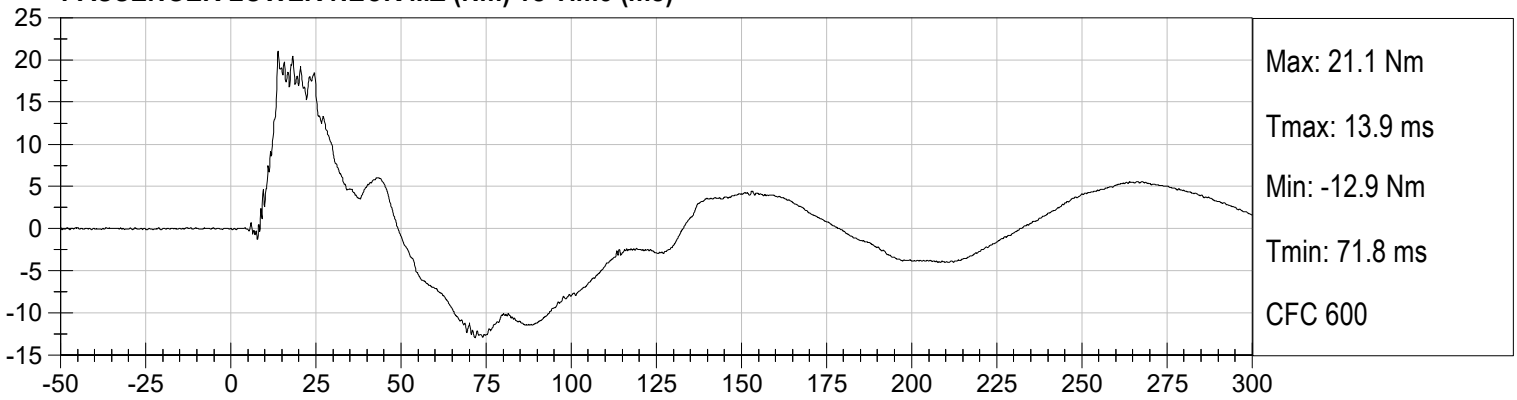
PASSENGER LOWER NECK MX (Nm) vs Time (ms)



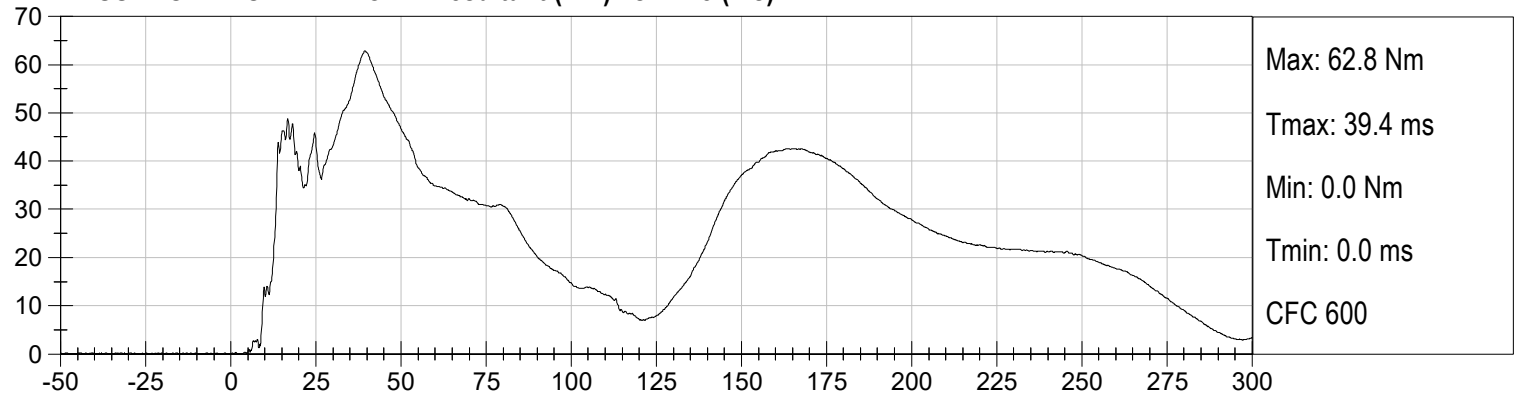
PASSENGER LOWER NECK MY (Nm) vs Time (ms)



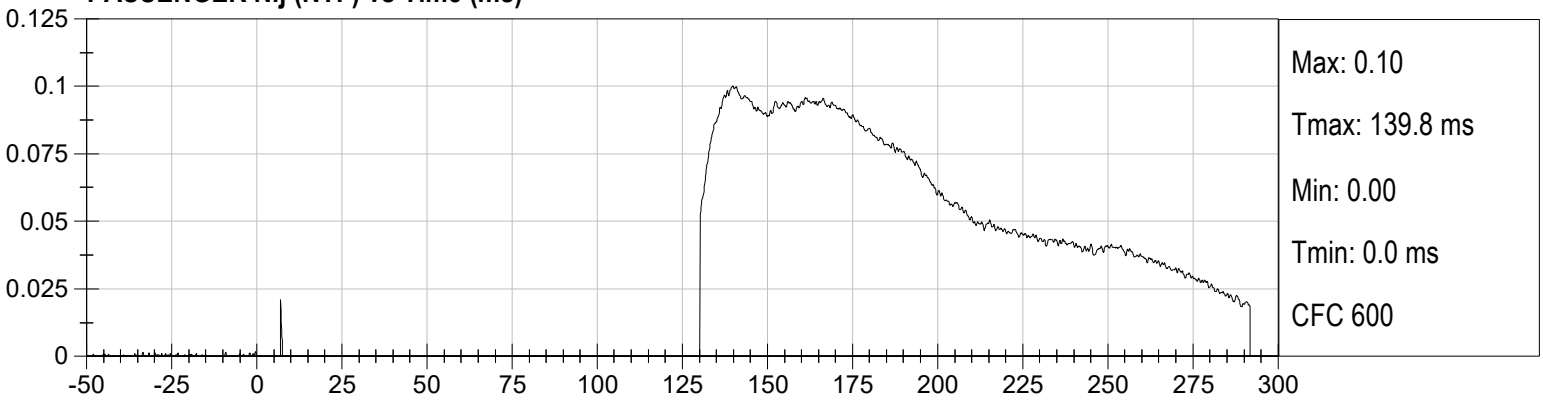
PASSENGER LOWER NECK MZ (Nm) vs Time (ms)



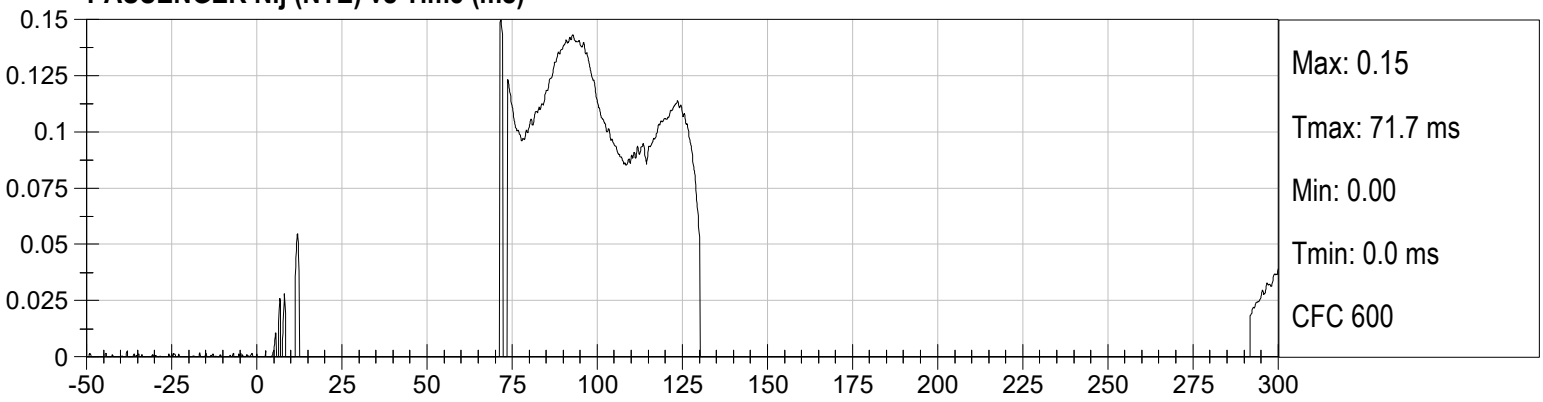
PASSENGER LOWER NECK MResultant (Nm) vs Time (ms)



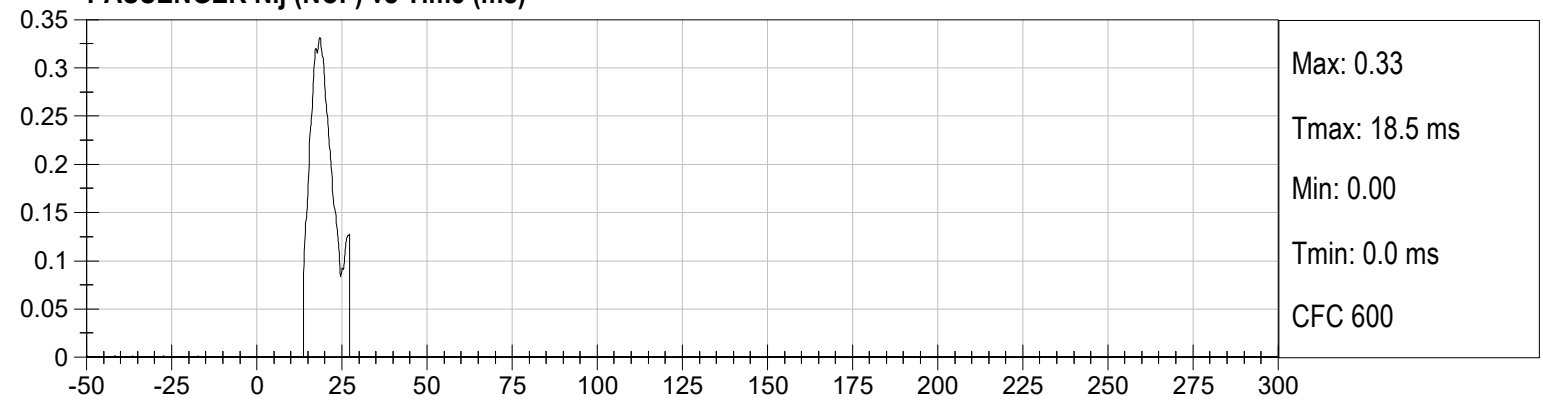
PASSENGER Nij (NTF) vs Time (ms)



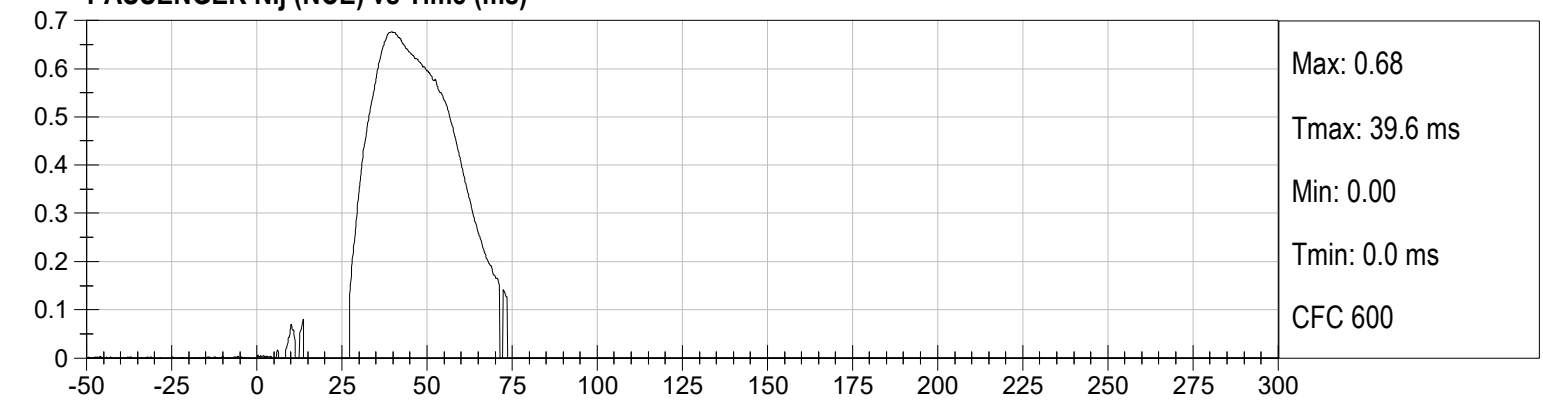
PASSENGER Nij (NTE) vs Time (ms)



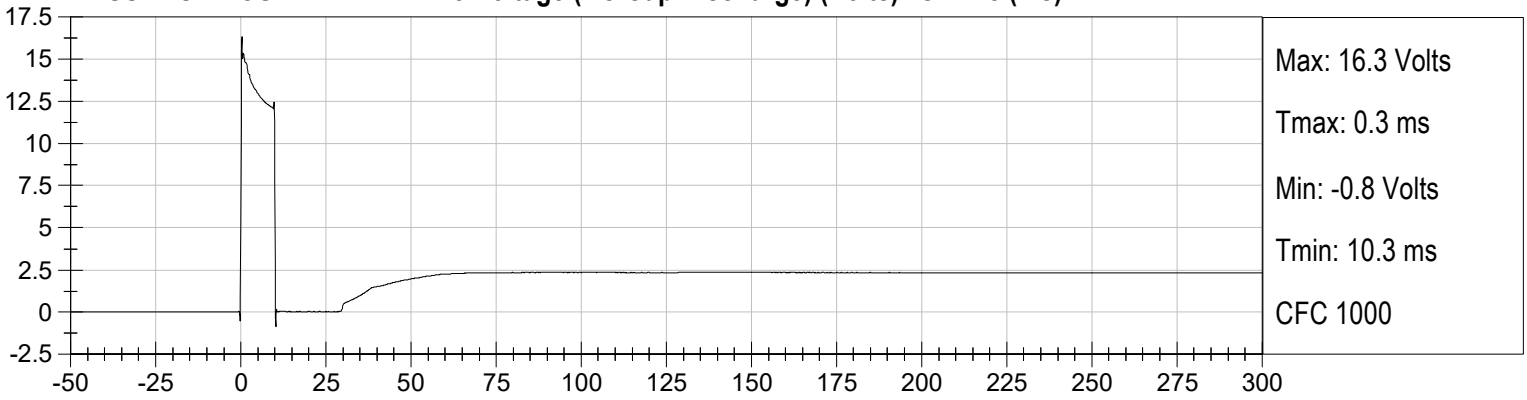
PASSENGER Nij (NCF) vs Time (ms)



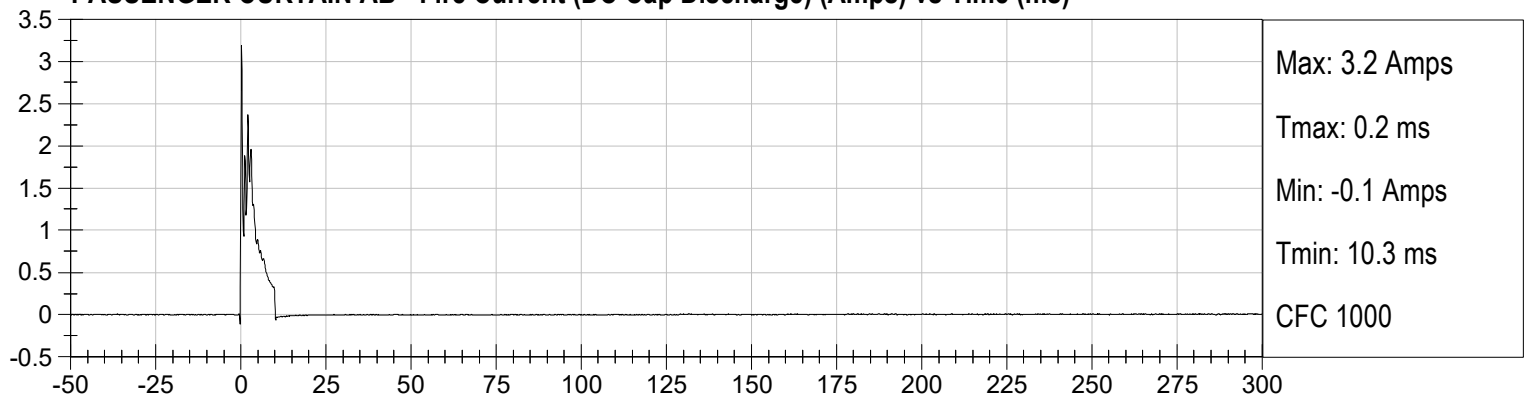
PASSENGER Nij (NCE) vs Time (ms)



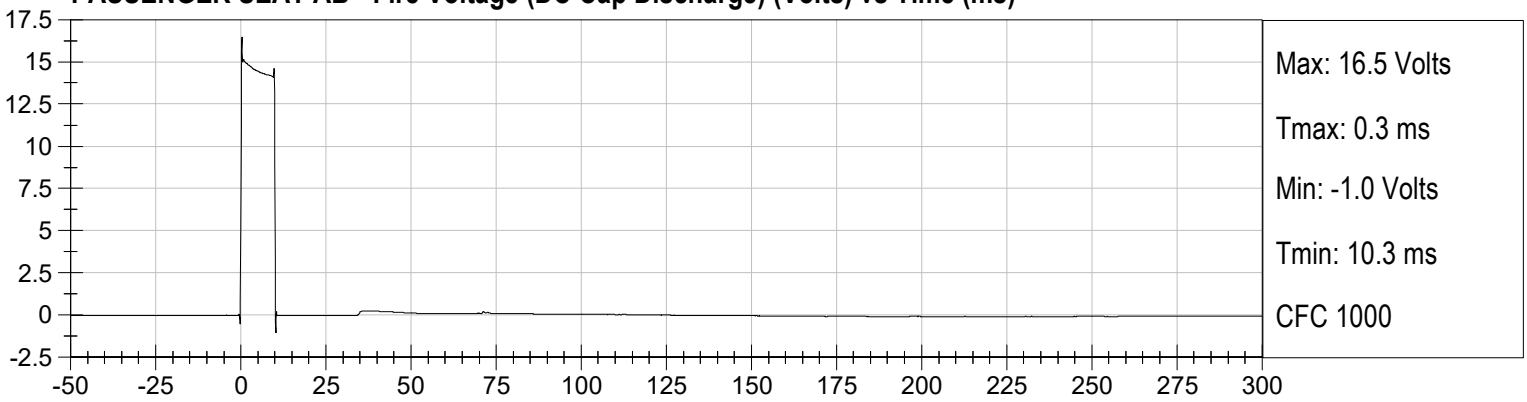
PASSENGER CURTAIN AB - Fire Voltage (DC Cap Discharge) (Volts) vs Time (ms)



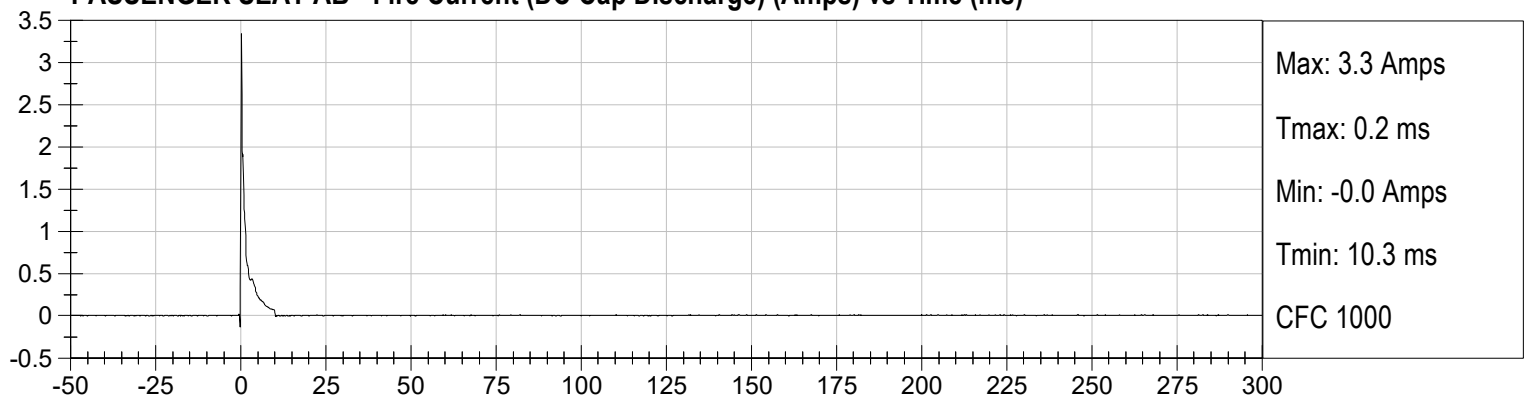
PASSENGER CURTAIN AB - Fire Current (DC Cap Discharge) (Amps) vs Time (ms)



PASSENGER SEAT AB - Fire Voltage (DC Cap Discharge) (Volts) vs Time (ms)



PASSENGER SEAT AB - Fire Current (DC Cap Discharge) (Amps) vs Time (ms)



APPENDIX C
DUMMY CONFIGURATION AND PERFORMANCE VERIFICATION DATA

CALIBRATION TEST RESULTS

PRE-TEST

SID-IIs ATD

MGA RESEARCH CORPORATION

HEAD DROP TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test ID:** D182631

Tested Parameter	Units	Specification	Result	Pass/Fail
Laboratory Temperature	deg C	20.6 to 22.2	21.5	Pass
Laboratory Relative Humidity	%	10 to 70	45	Pass
Peak Resultant Acceleration	G's	115 to 137	123	Pass
Peak Longitudinal Acceleration	G's	+/- 15	6.9	Pass
Unimodal	N/A	Yes	Yes	Pass
Oscillations	N/A	<15%	Yes	Pass
		Overall Test Results		Pass

Jacob D Taylor
Laboratory Technician

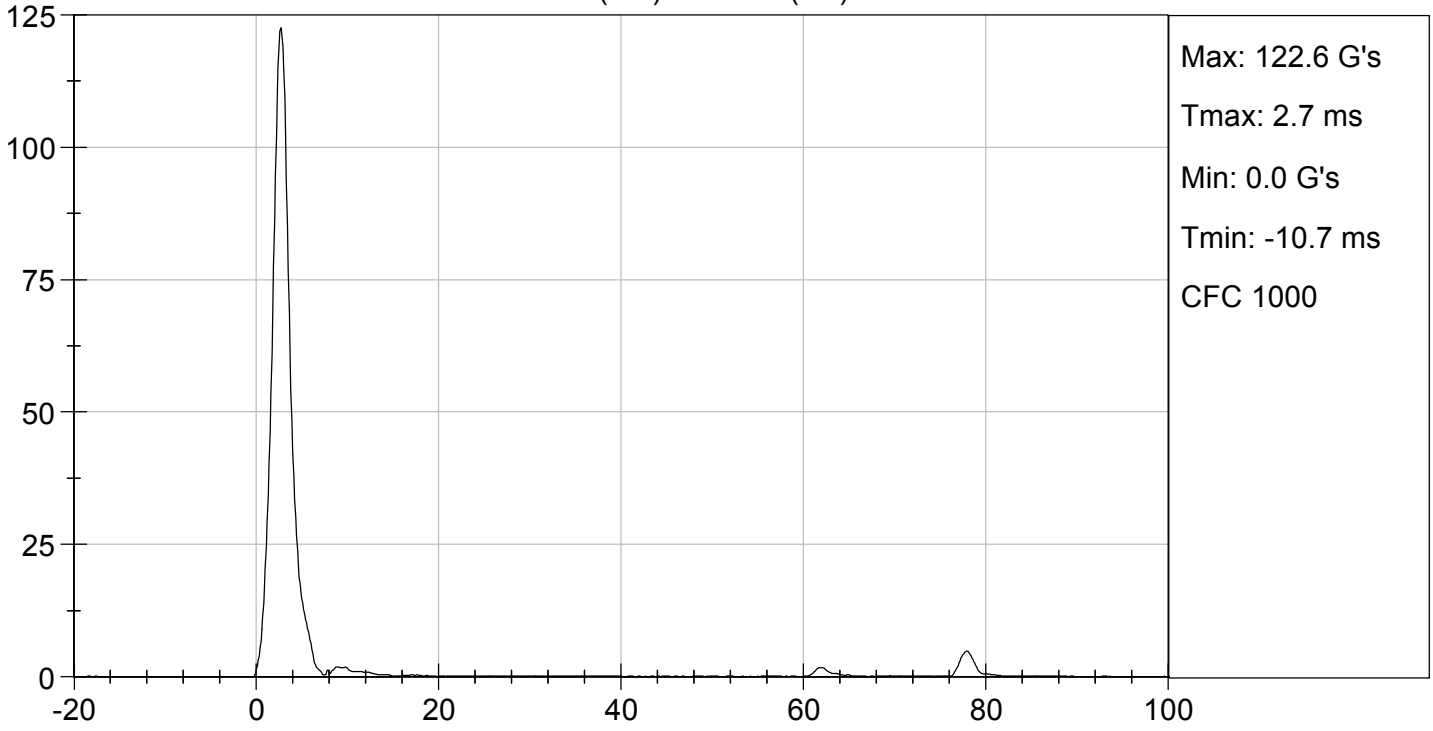
08/23/2018
Test Date

Approved By

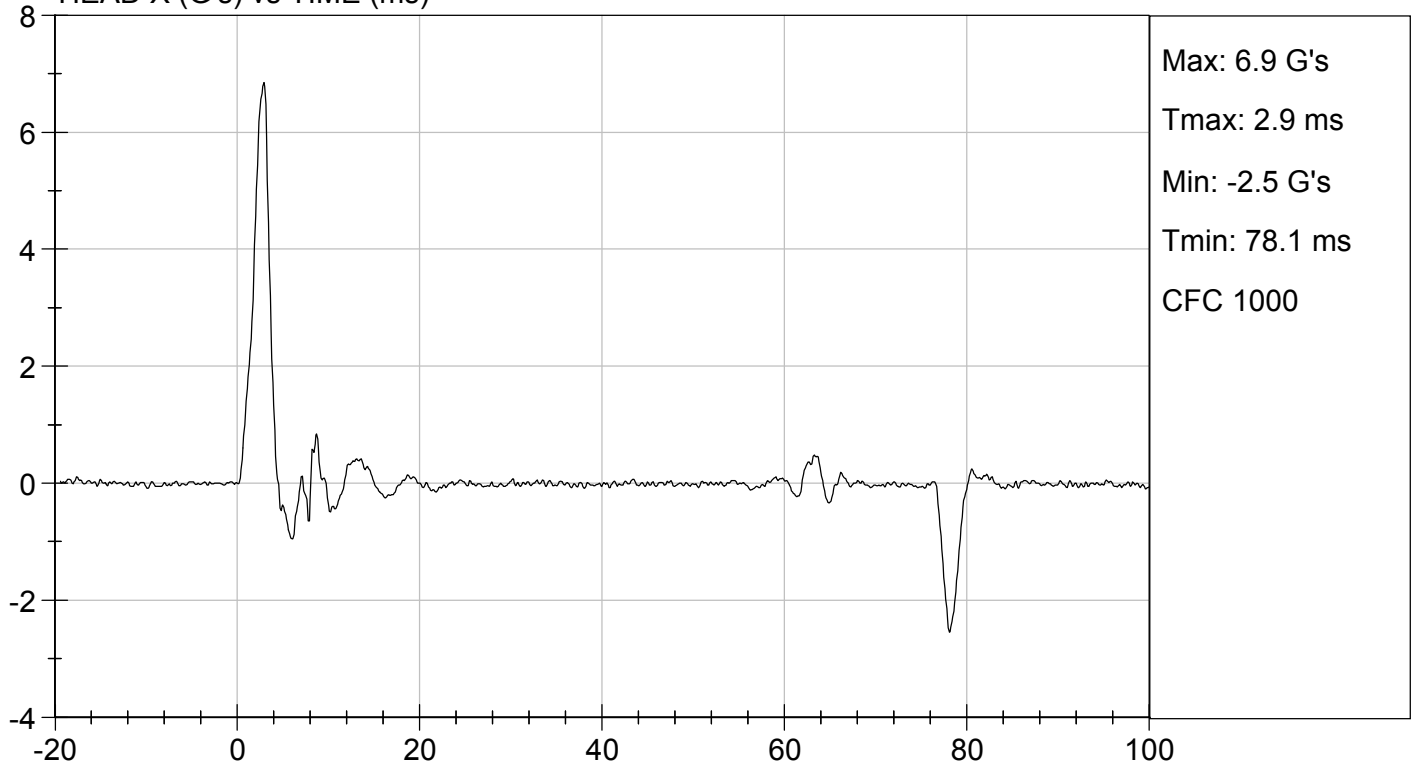
TEST DESC: HEAD DROP

TEST DATE: 08/23/2018
TEST #: D182631

HEAD RESULTANT ACCELERATION (G's) vs TIME (ms)

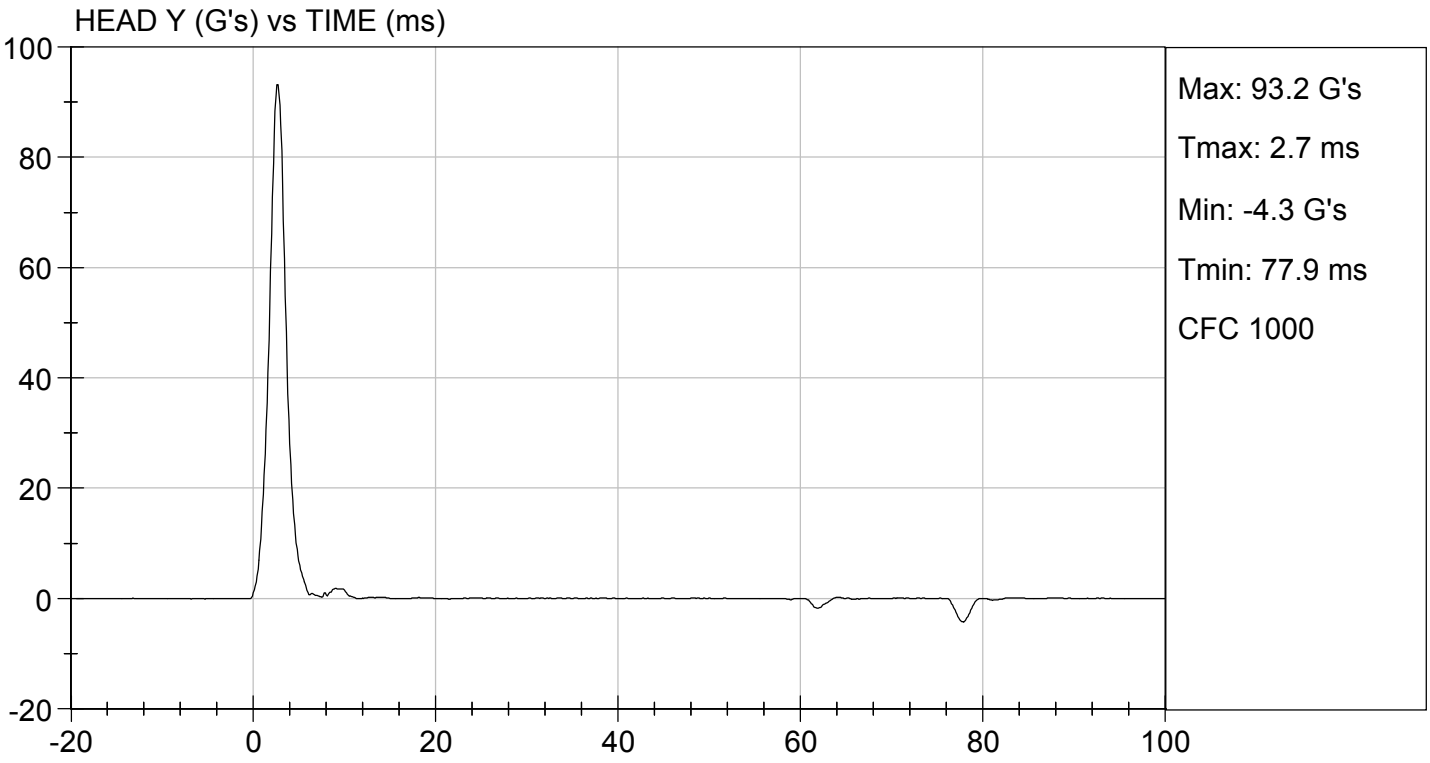


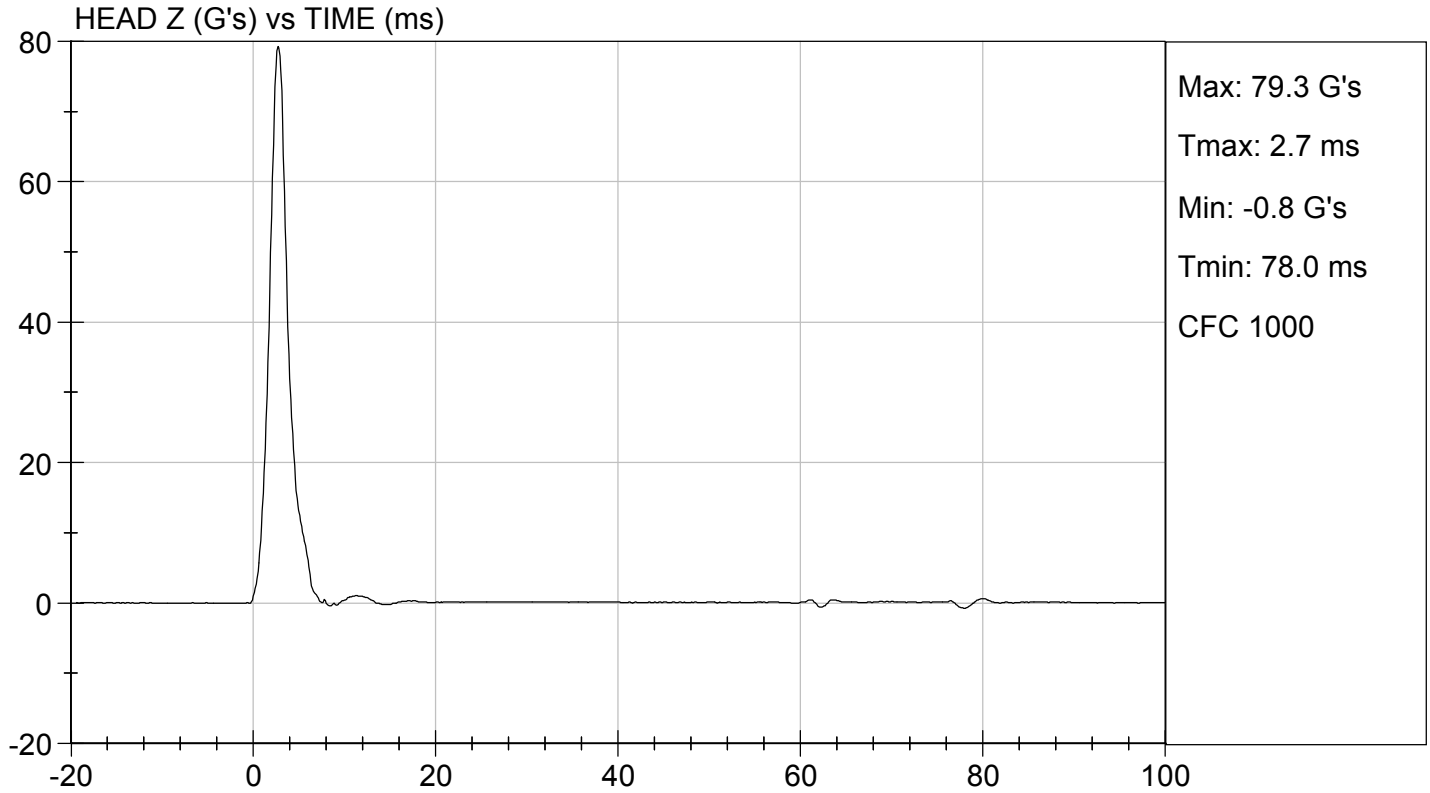
HEAD X (G's) vs TIME (ms)



TEST DESC: HEAD DROP

TEST DATE: 08/23/2018
TEST #: D182631





MGA RESEARCH CORPORATION

LATERAL NECK PENDULUM TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182632

Tested Parameter		Units	Specification	Result	Pass/Fail
Temperature		deg C	20.6 to 22.2	21.5	Pass
Humidity		%	10 to 70	44	Pass
Impact Velocity		m/s	5.51 to 5.63	5.58	Pass
Pendulum Velocity	10 ms	m/s	2.20 to 2.80	2.54	Pass
	15 ms	m/s	3.30 to 4.10	3.83	Pass
	20 ms	m/s	4.40 to 5.40	5.26	Pass
	25 ms	m/s	5.40 to 6.10	5.55	Pass
	25-100 ms	m/s	5.50 to 6.20	5.59	Pass
Maximum D-Plane Rotation		deg	71 to 81	74	Pass
Time of Maximum D-Plane Rotation		ms	50 to 70	64	Pass
Maximum Occipital Condyle Moment		Nm	-44 to -36	-41	Pass
Time of Moment Decay to 0 Nm		ms	102 to 126	113	Pass
			Overall Test Results		Pass

Emily Fliess

Laboratory Technician

08/23/2018

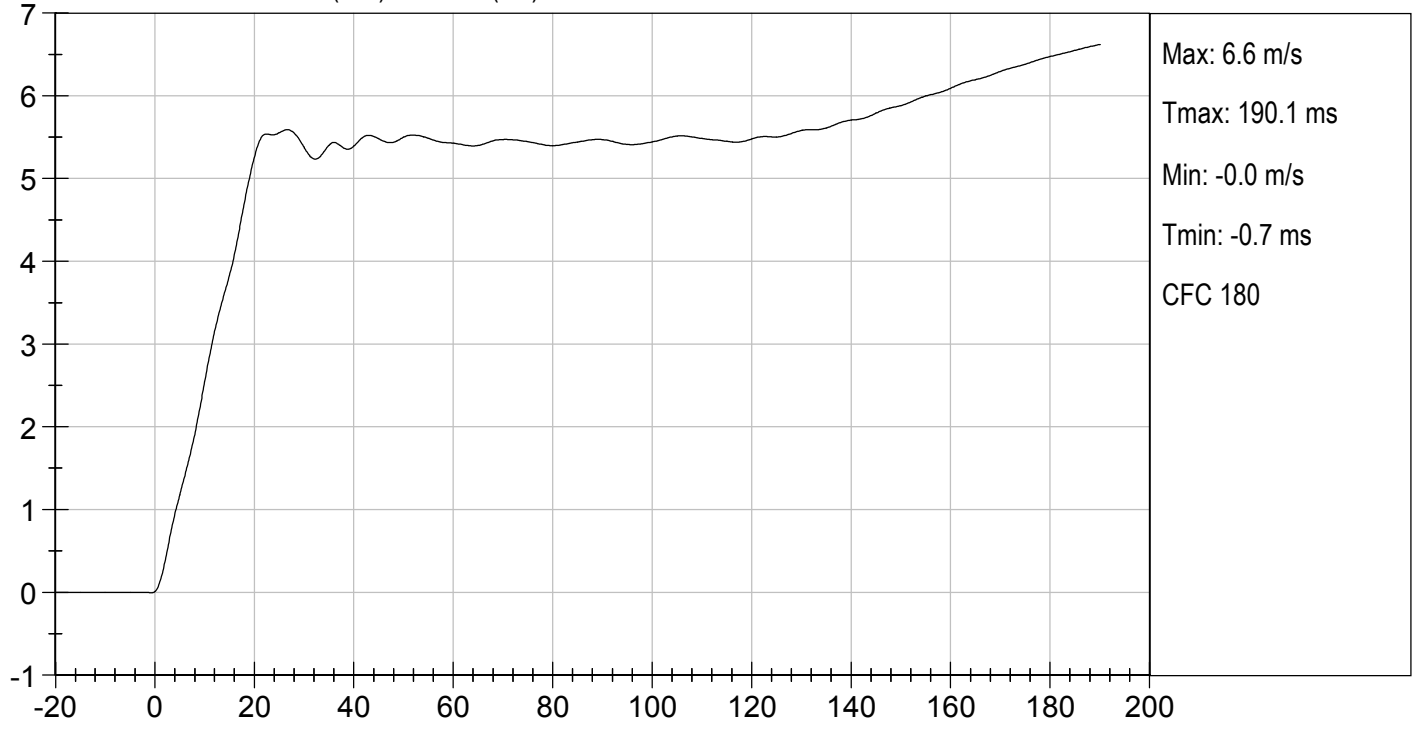
Test Date

Approved By

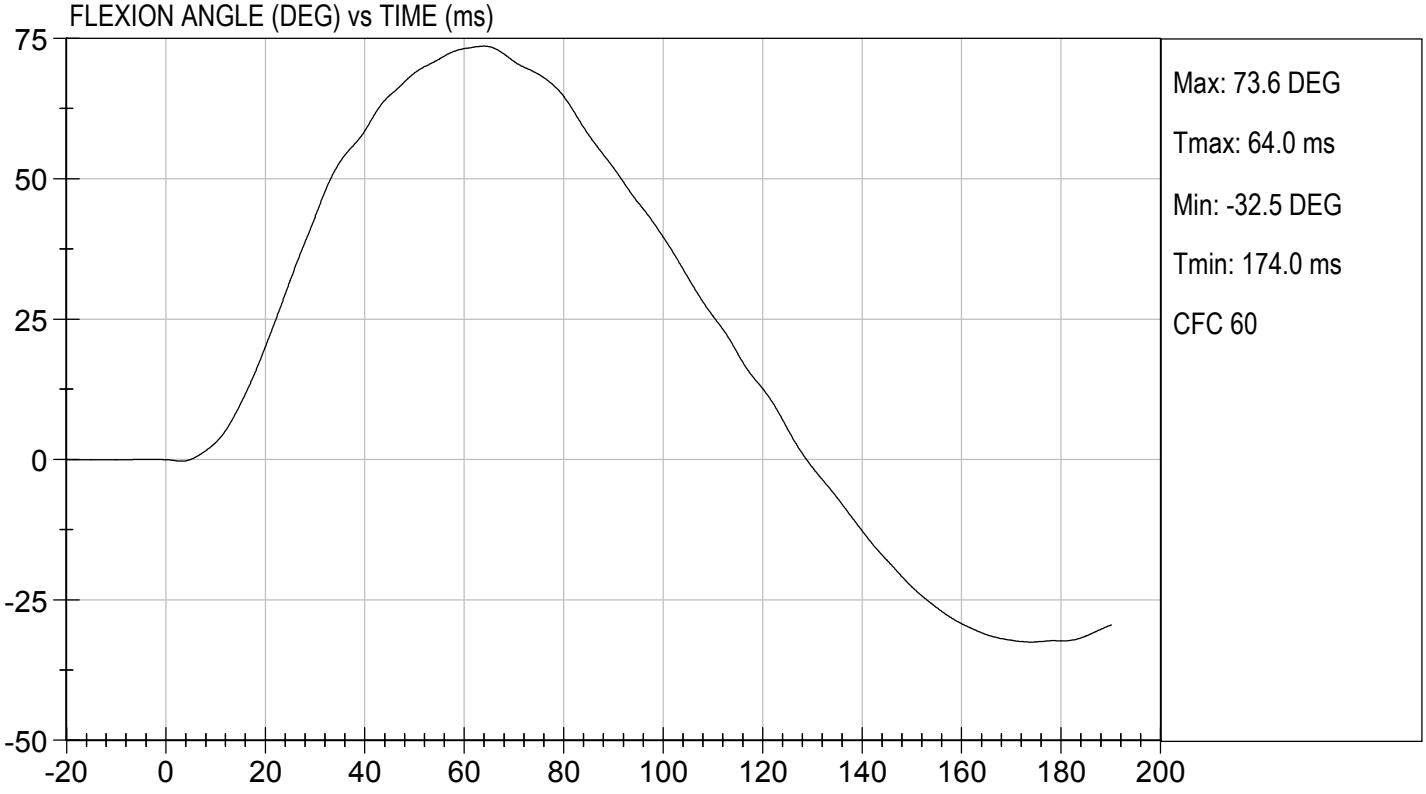
TEST DESC: NECK BENDING
VELOCITY: 18.32 ft/s, 5.58 m/s

TEST DATE: 08/23/2018
TEST #: D182632

PENDULUM VELOCITY (m/s) vs TIME (ms)

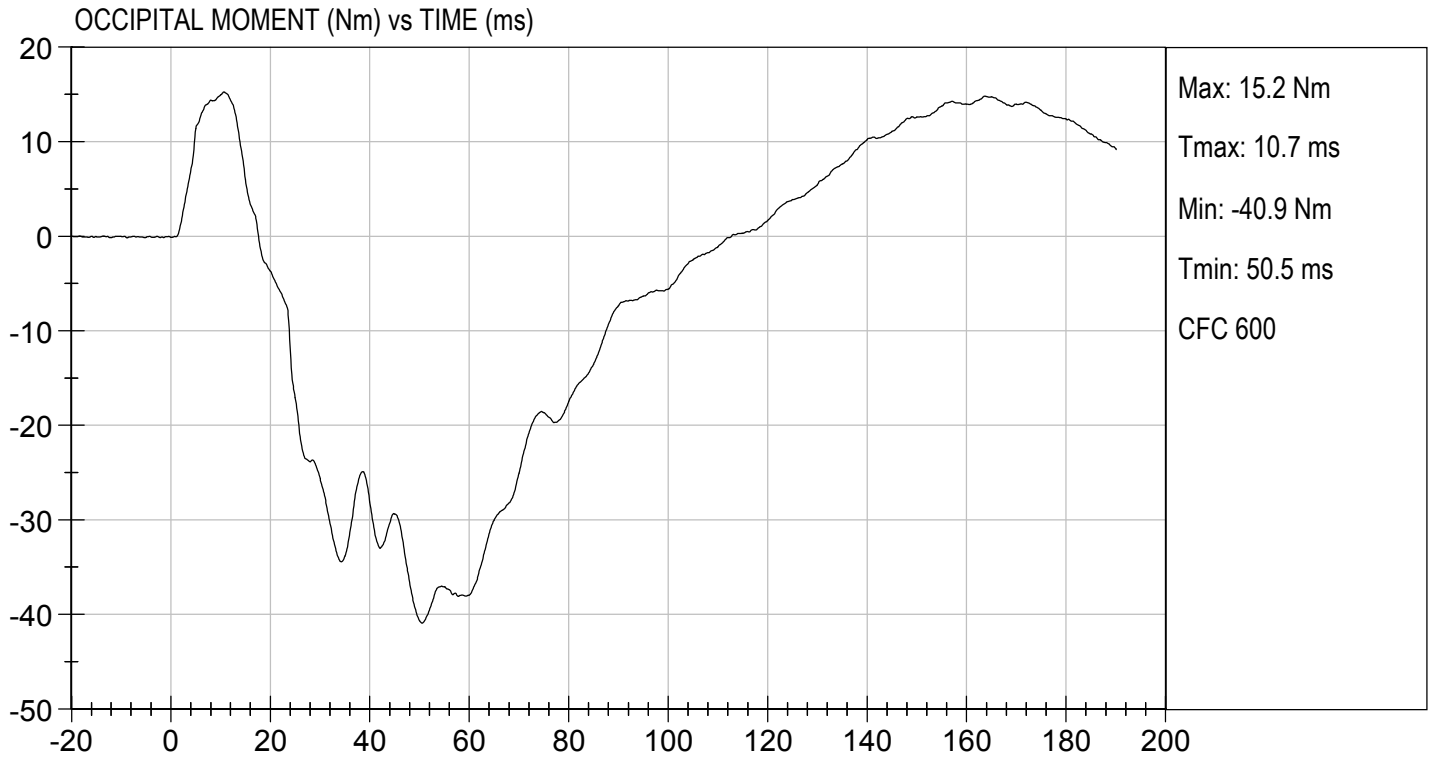


FLEXION ANGLE (DEG) vs TIME (ms)



TEST DESC: NECK BENDING
VELOCITY: 18.32 ft/s, 5.58 m/s

TEST DATE: 08/23/2018
TEST #: D182632



MGA RESEARCH CORPORATION

SHOULDER IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test ID:** D182633

Tested Parameter	Units	Specification	Result	Pass/Fail
Laboratory Temperature	deg C	20.6 to 22.2	21.6	Pass
Laboratory Relative Humidity	%	10 to 70	51	Pass
Impact Velocity	m/s	4.20 to 4.40	4.38	Pass
Maximum Probe Acceleration	G's	13 to 18	16	Pass
Shoulder Displacement	mm	28 to 37	32	Pass
Upper Spine (T1) Y Acceleration	G's	17 to 22	19	Pass
		Overall Test Results		Pass

Danielle Redinbaugh
Laboratory Technician

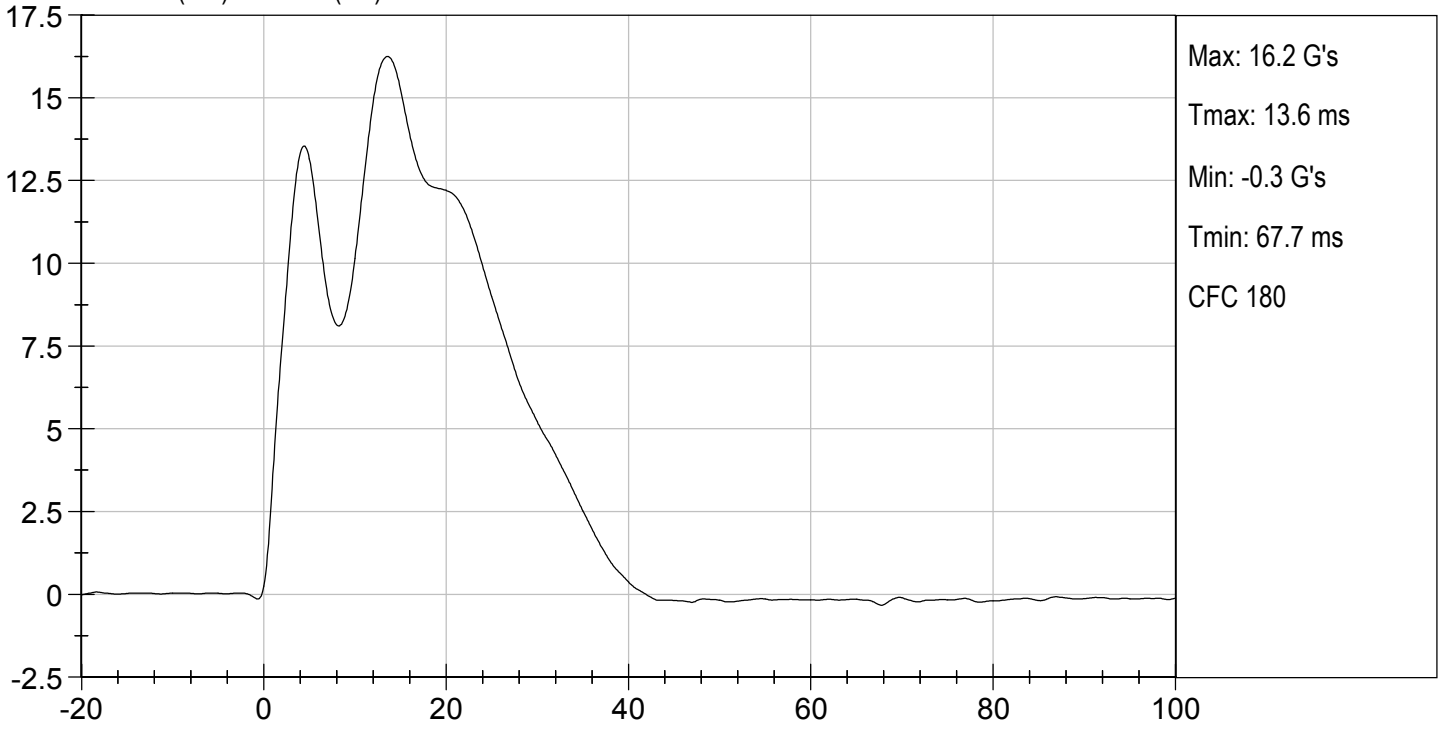
08/27/2018
Test Date

Approved By

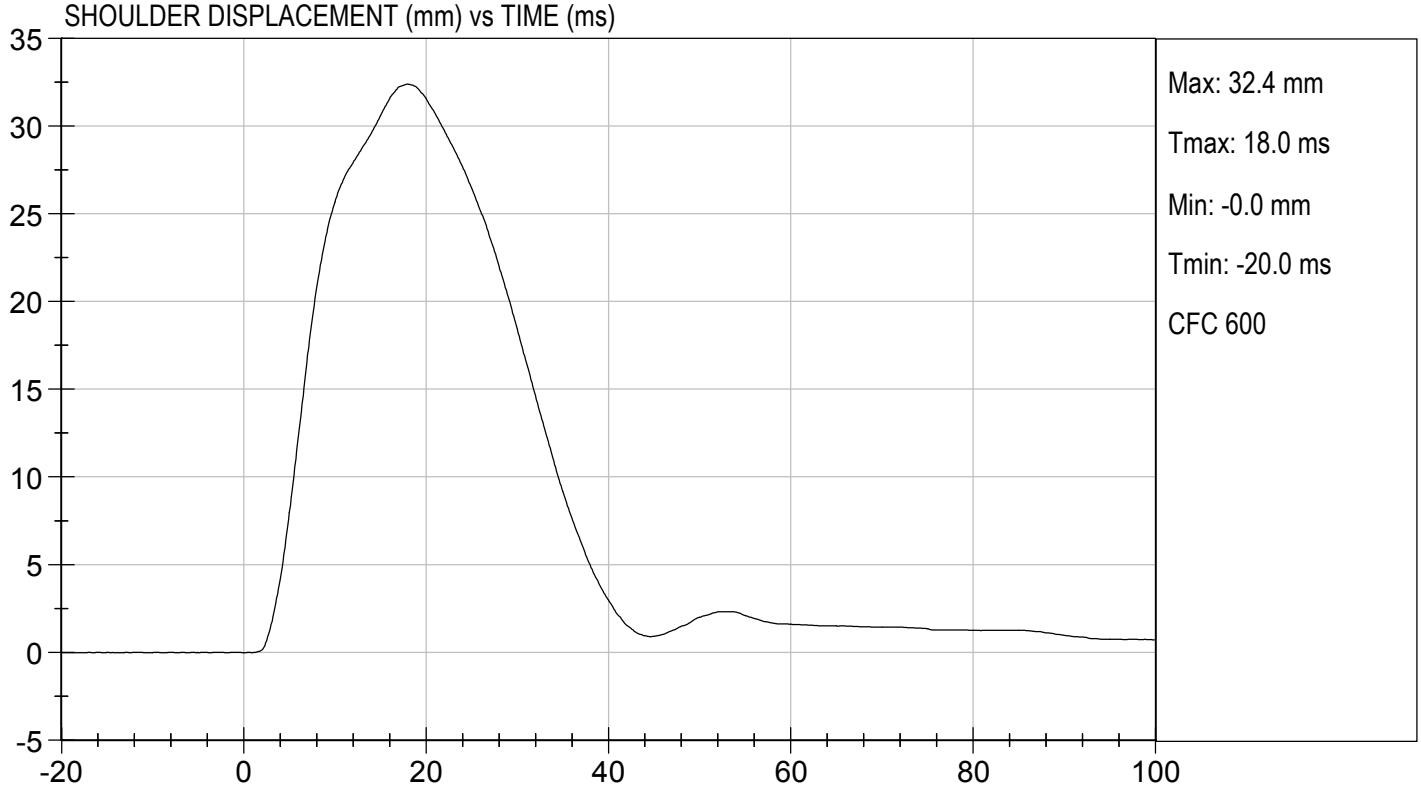
TEST DESC: SHOULDER IMPACT
VELOCITY: 14.37 ft/s, 4.38 m/s

TEST DATE: 08/27/2018
TEST #: D182633

PROBE (G's) vs TIME (ms)

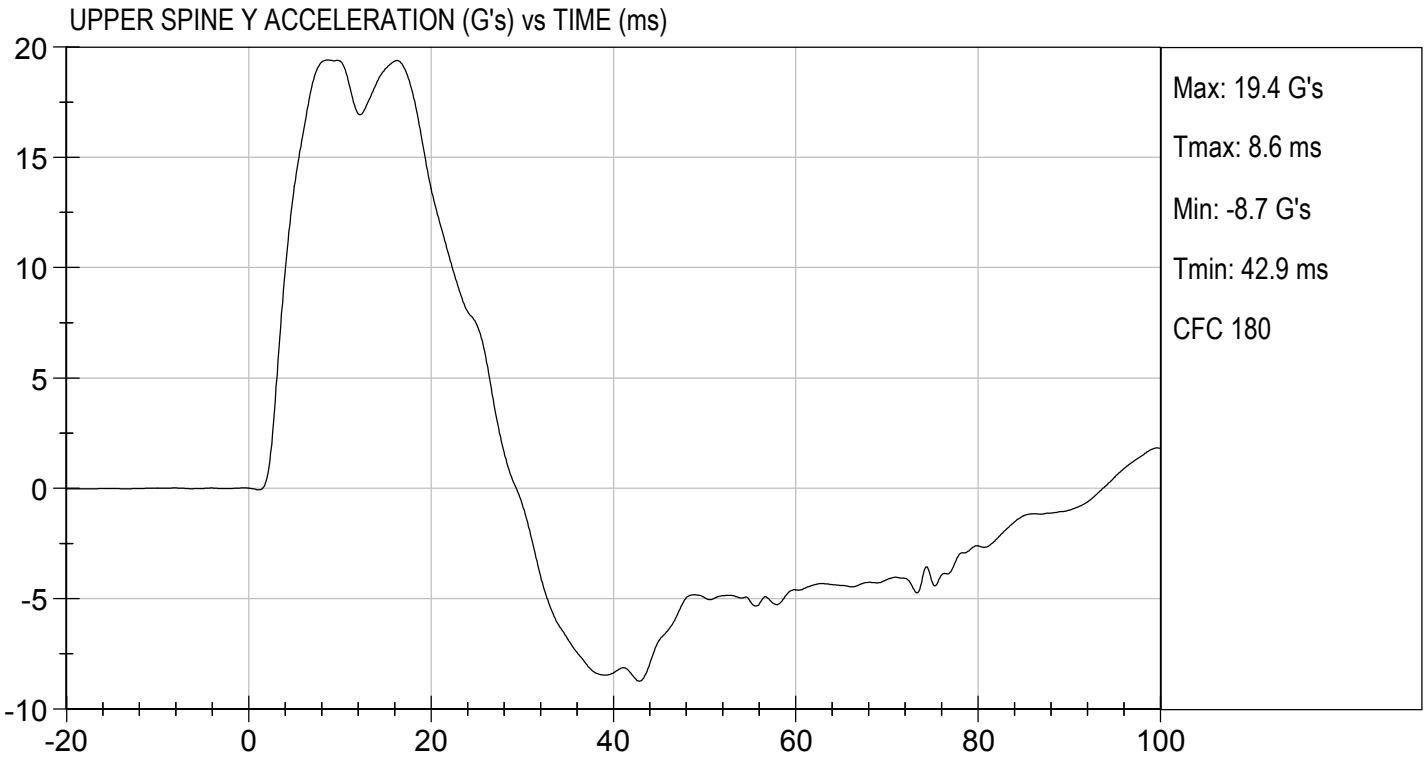


SHOULDER DISPLACEMENT (mm) vs TIME (ms)



TEST DESC: SHOULDER IMPACT
VELOCITY: 14.37 ft/s, 4.38 m/s

TEST DATE: 08/27/2018
TEST #: D182633



MGA RESEARCH CORPORATION

THORAX (WITH ARM) IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182634

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.6	Pass
Humidity	%	10 to 70	51	Pass
Impact Velocity	m/s	6.60 to 6.80	6.80	Pass
Maximum Probe Acceleration	G's	30 to 36	35	Pass
Shoulder Displacement	mm	31 to 40	36	Pass
Upper Rib Displacement	mm	25 to 32	28	Pass
Middle Rib Displacement	mm	30 to 36	32	Pass
Lower Rib Displacement	mm	32 to 38	33	Pass
Upper Spine (T1) Y Acceleration	G's	34 to 43	40	Pass
Lower Spine (T12) Y Acceleration	G's	29 to 37	34	Pass
		Overall Test Results		Pass

Danielle Redinbaugh
Laboratory Technician

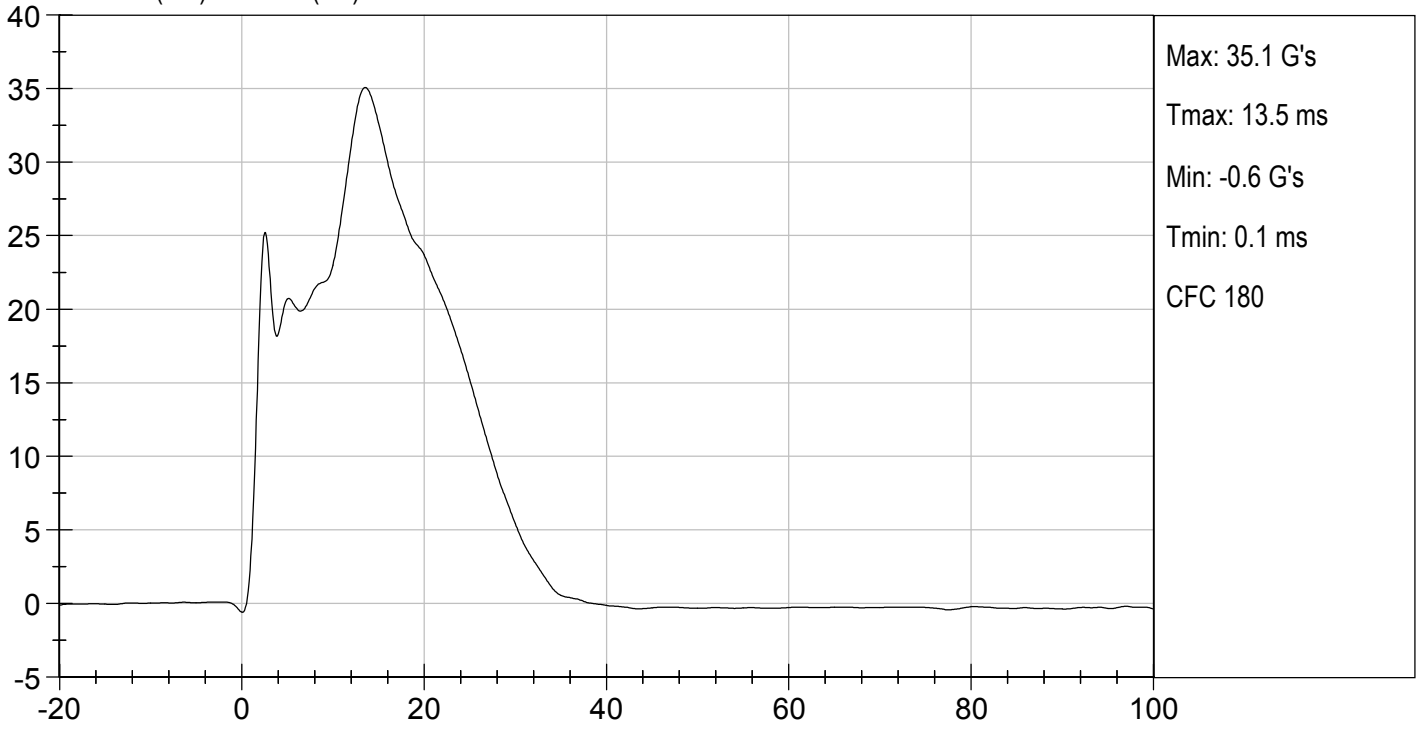
08/27/2018
Test Date

Approved By

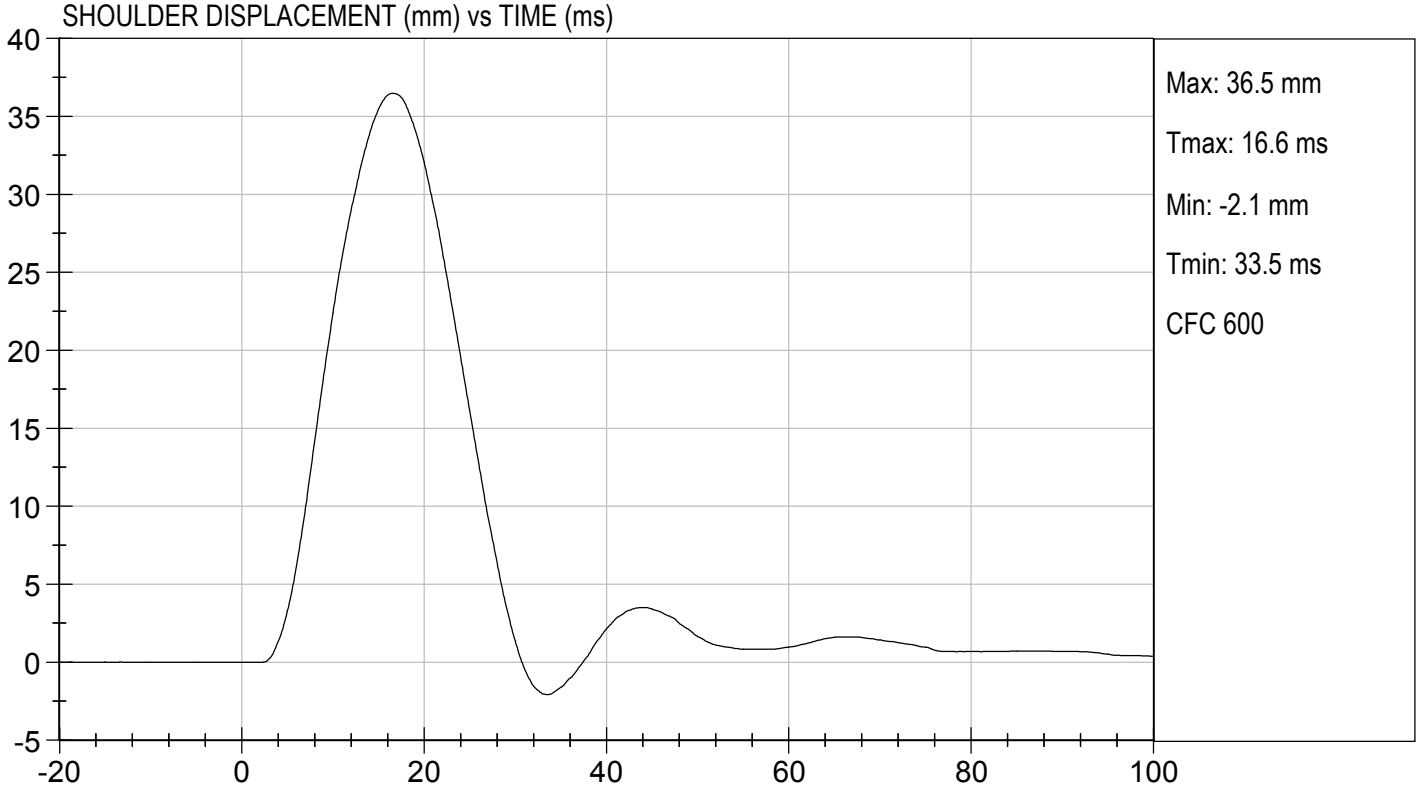
TEST DESC: THORAX IMPACT WITH ARM
VELOCITY: 22.30 ft/s, 6.80 m/s

TEST DATE: 08/27/2018
TEST #: D182634

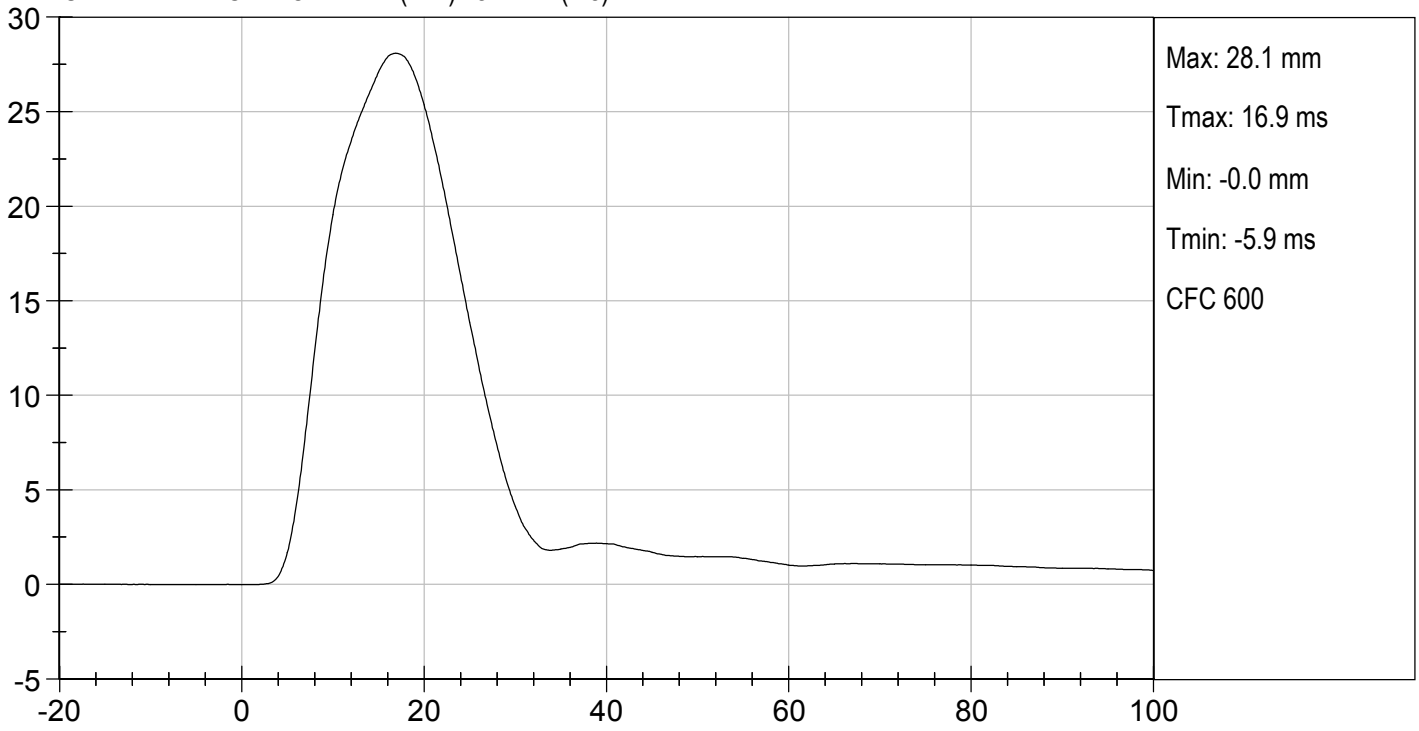
PROBE (G's) vs TIME (ms)



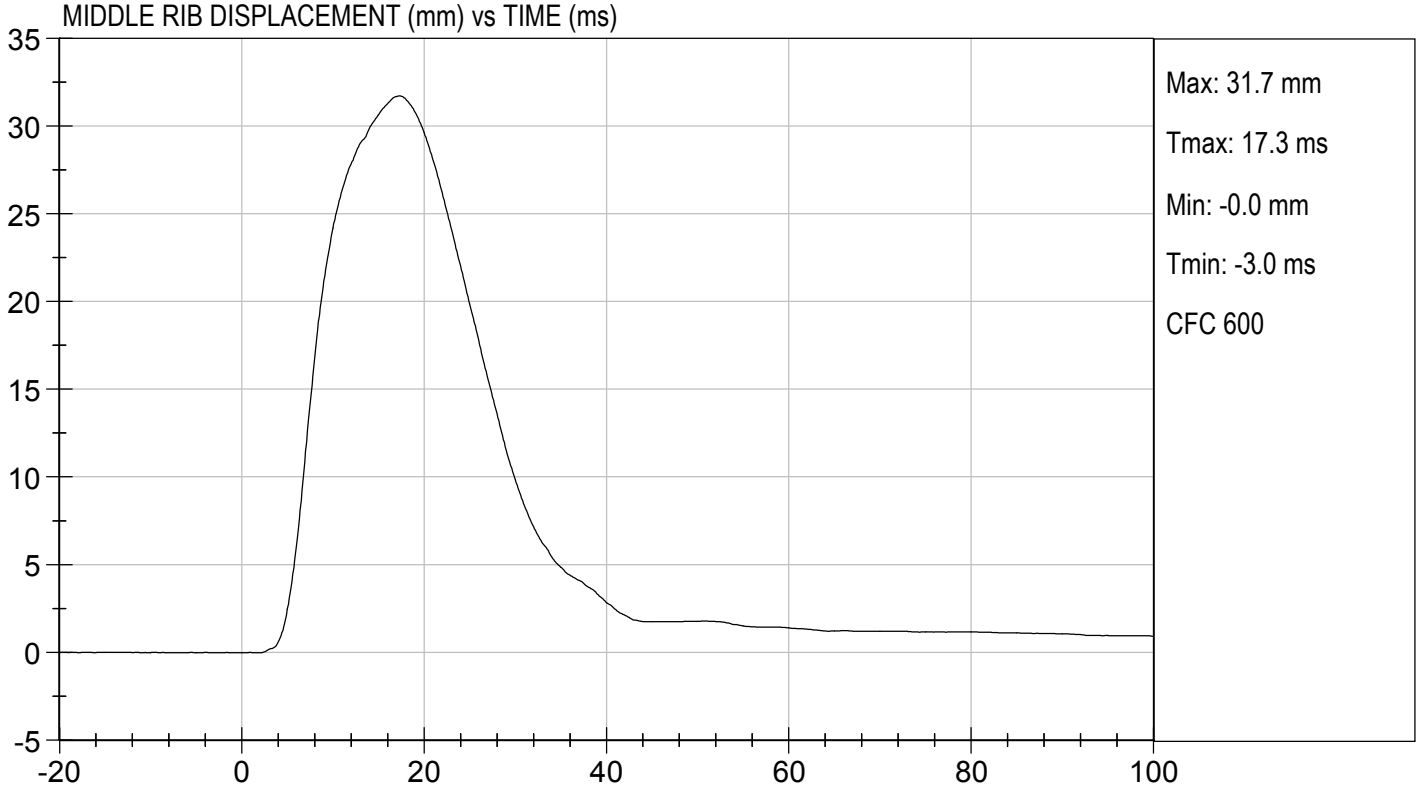
SHOULDER DISPLACEMENT (mm) vs TIME (ms)



UPPER RIB DISPLACEMENT (mm) vs TIME (ms)



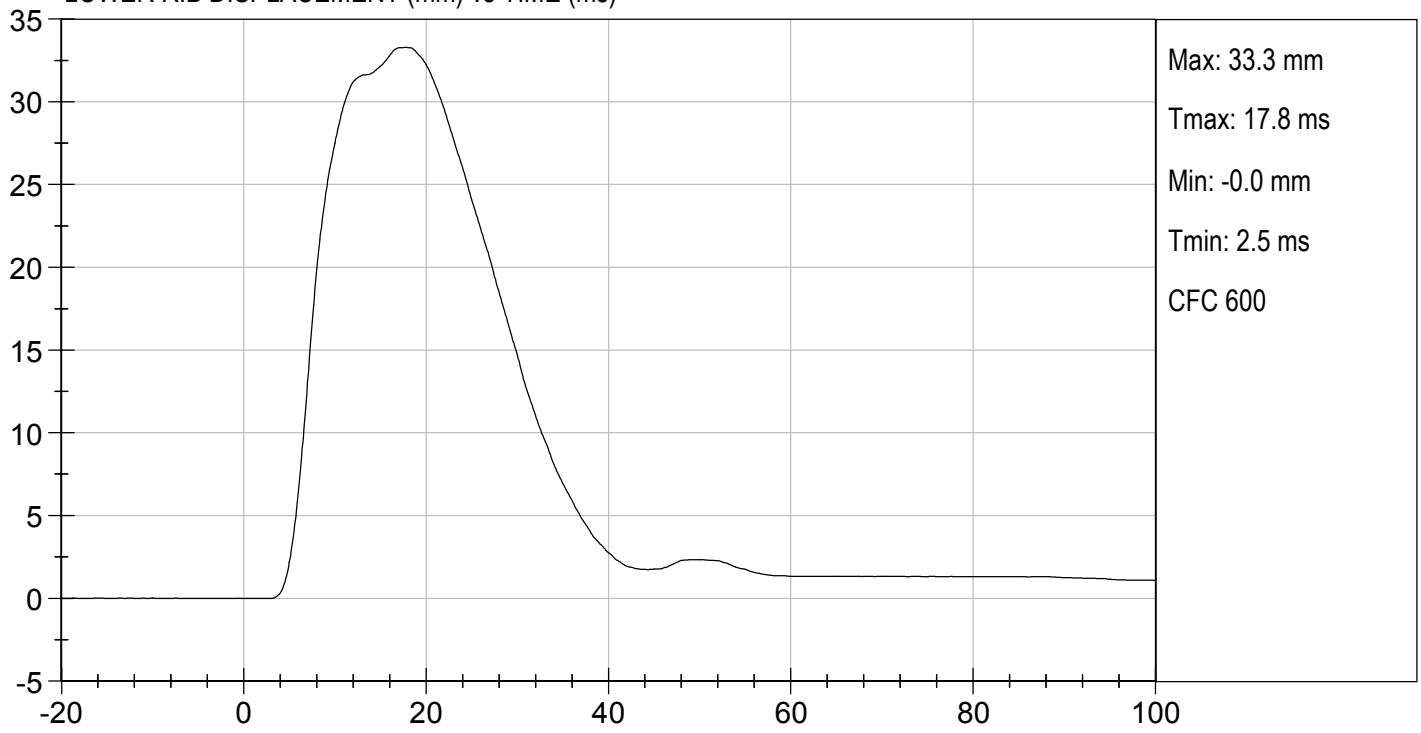
MIDDLE RIB DISPLACEMENT (mm) vs TIME (ms)



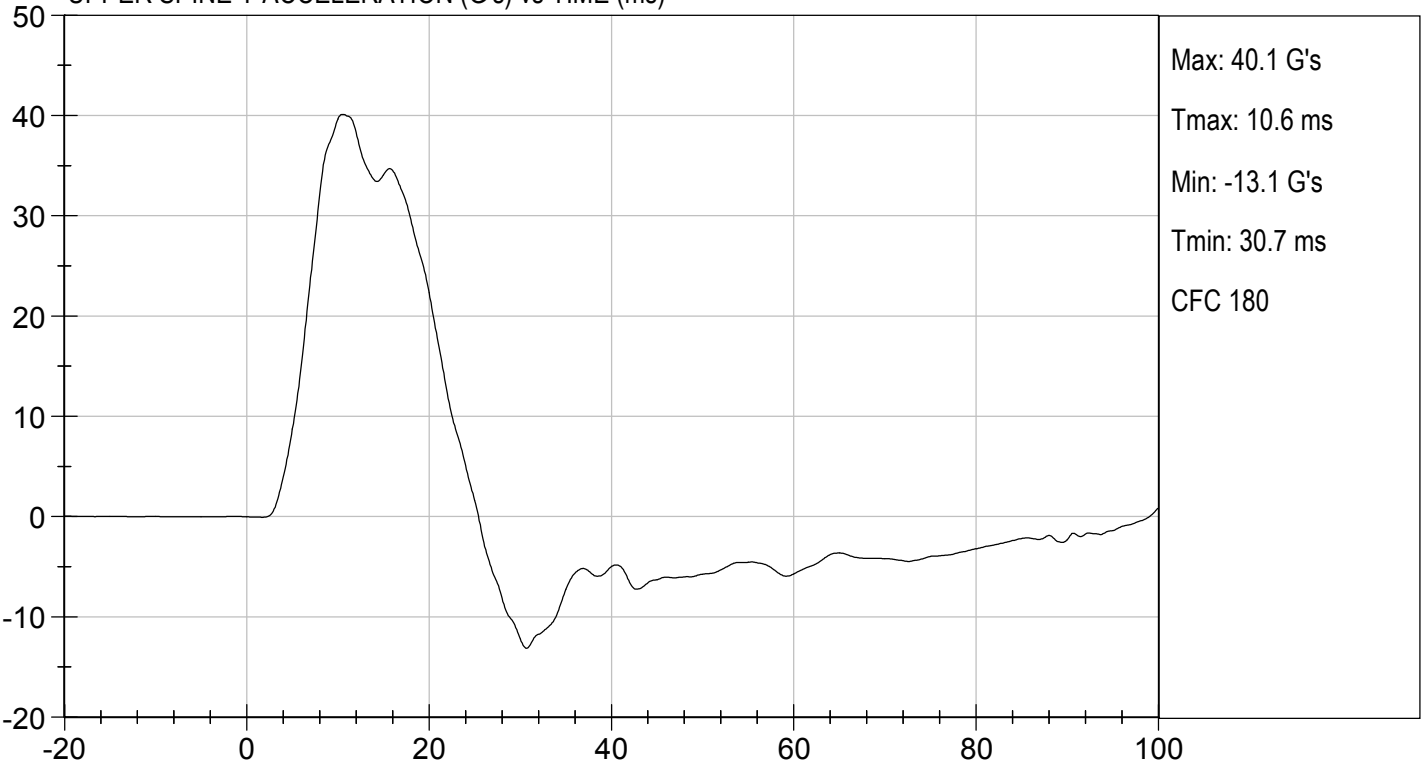
TEST DESC: THORAX IMPACT WITH ARM
VELOCITY: 22.30 ft/s, 6.80 m/s

TEST DATE: 08/27/2018
TEST #: D182634

LOWER RIB DISPLACEMENT (mm) vs TIME (ms)

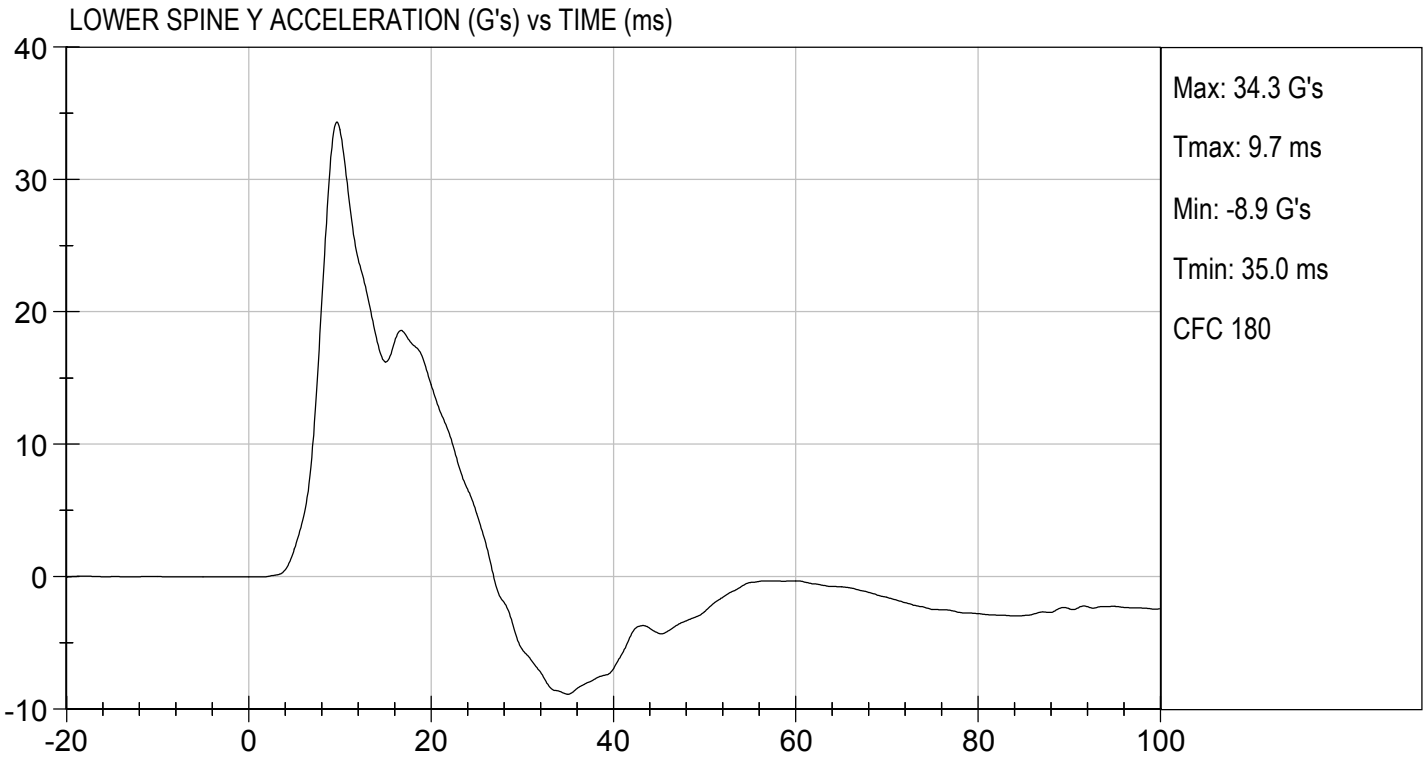


UPPER SPINE Y ACCELERATION (G's) vs TIME (ms)



TEST DESC: THORAX IMPACT WITH ARM
VELOCITY: 22.30 ft/s, 6.80 m/s

TEST DATE: 08/27/2018
TEST #: D182634



MGA RESEARCH CORPORATION

THORAX (WITHOUT ARM) IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182635

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.6	Pass
Humidity	%	10 to 70	51	Pass
Impact Velocity	m/s	4.20 to 4.40	4.38	Pass
Maximum Probe Acceleration	G's	14 to 18	17	Pass
Upper Rib Displacement	mm	32 to 40	35	Pass
Middle Rib Displacement	mm	39 to 45	41	Pass
Lower Rib Displacement	mm	35 to 43	40	Pass
Upper Spine (T1) Y Acceleration	G's	13 to 17	16	Pass
Lower Spine (T12) Y Acceleration	G's	7 to 11	10	Pass
		Overall Test Results		Pass

Danielle Redinbaugh
Laboratory Technician

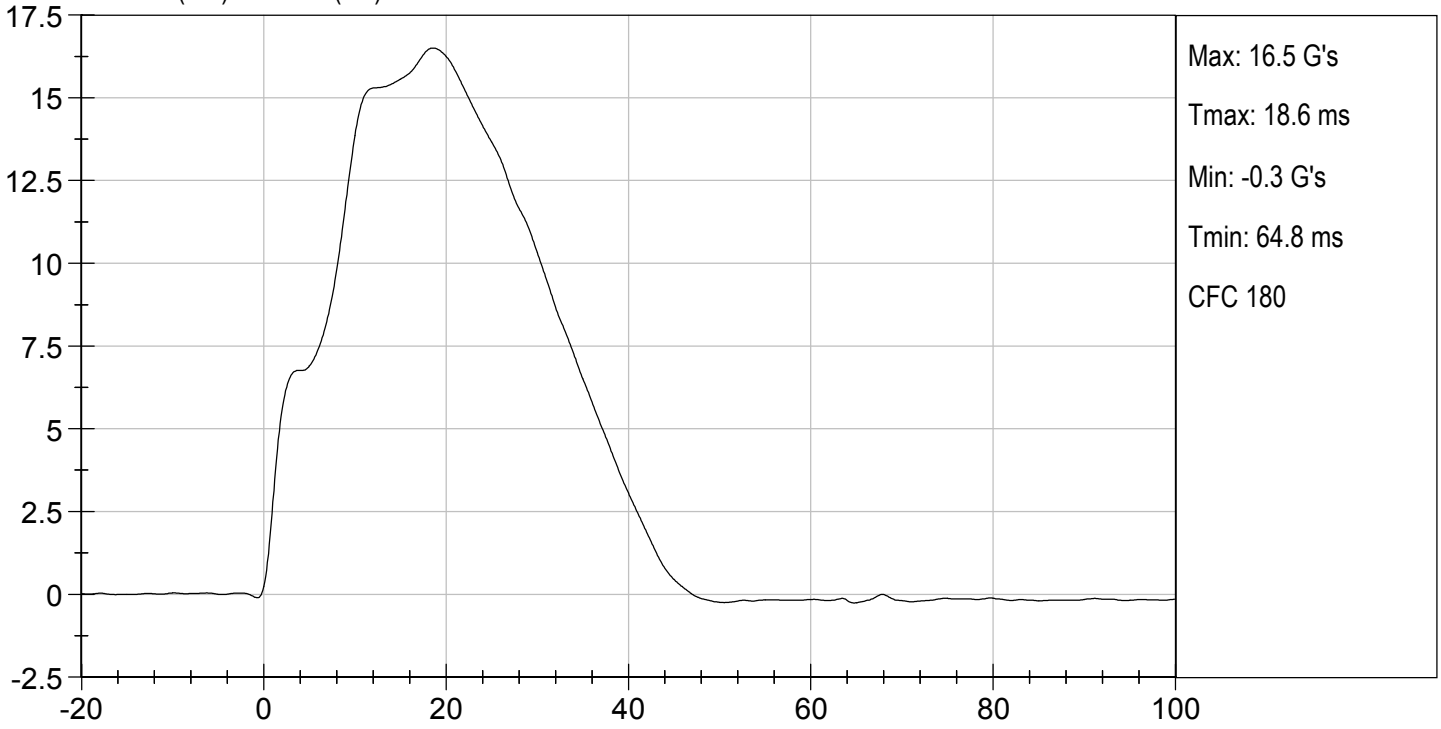
08/27/2018
Test Date

Approved By

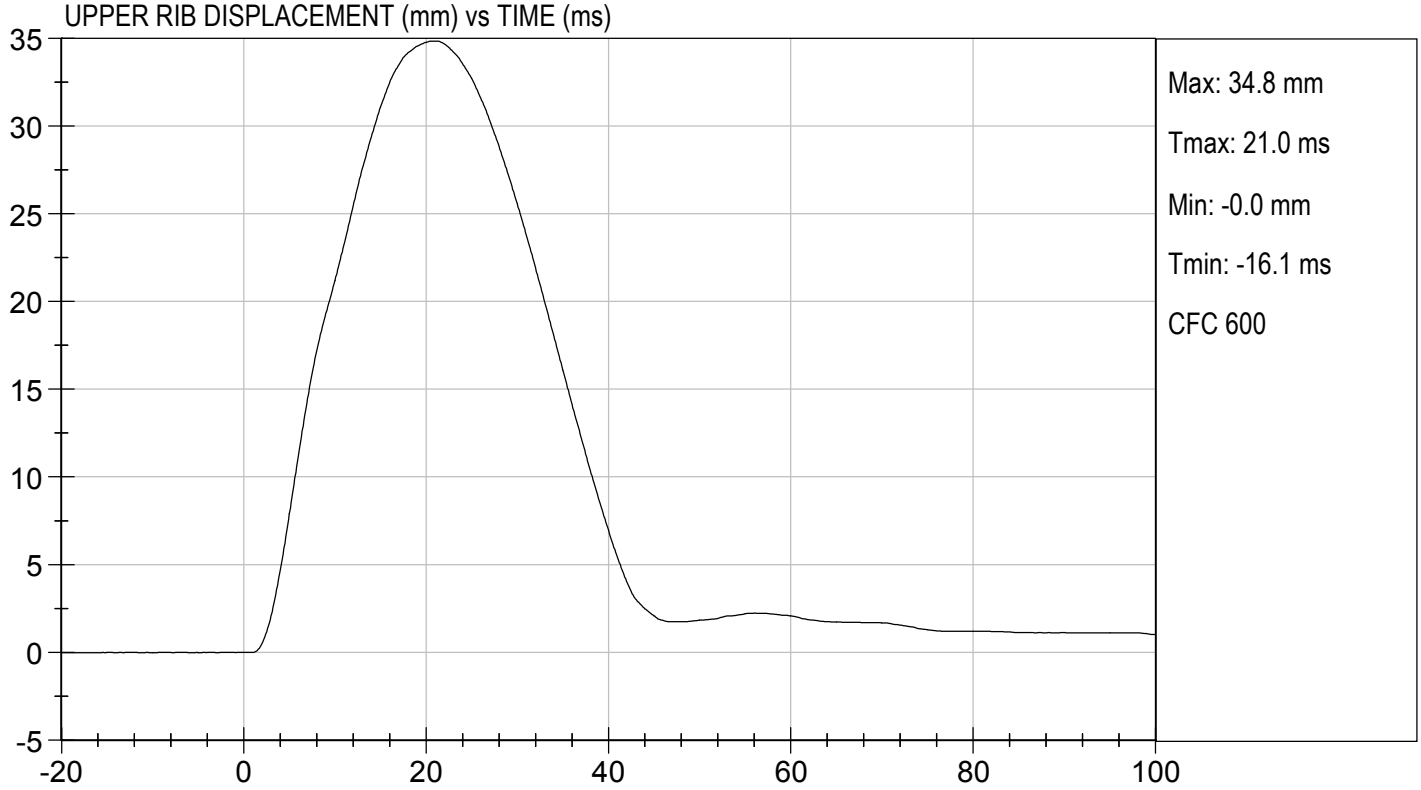
TEST DESC: THORAX IMPACT WITHOUT ARM
VELOCITY: 14.37 ft/s, 4.38 m/s

TEST DATE: 08/27/2018
TEST #: D182635

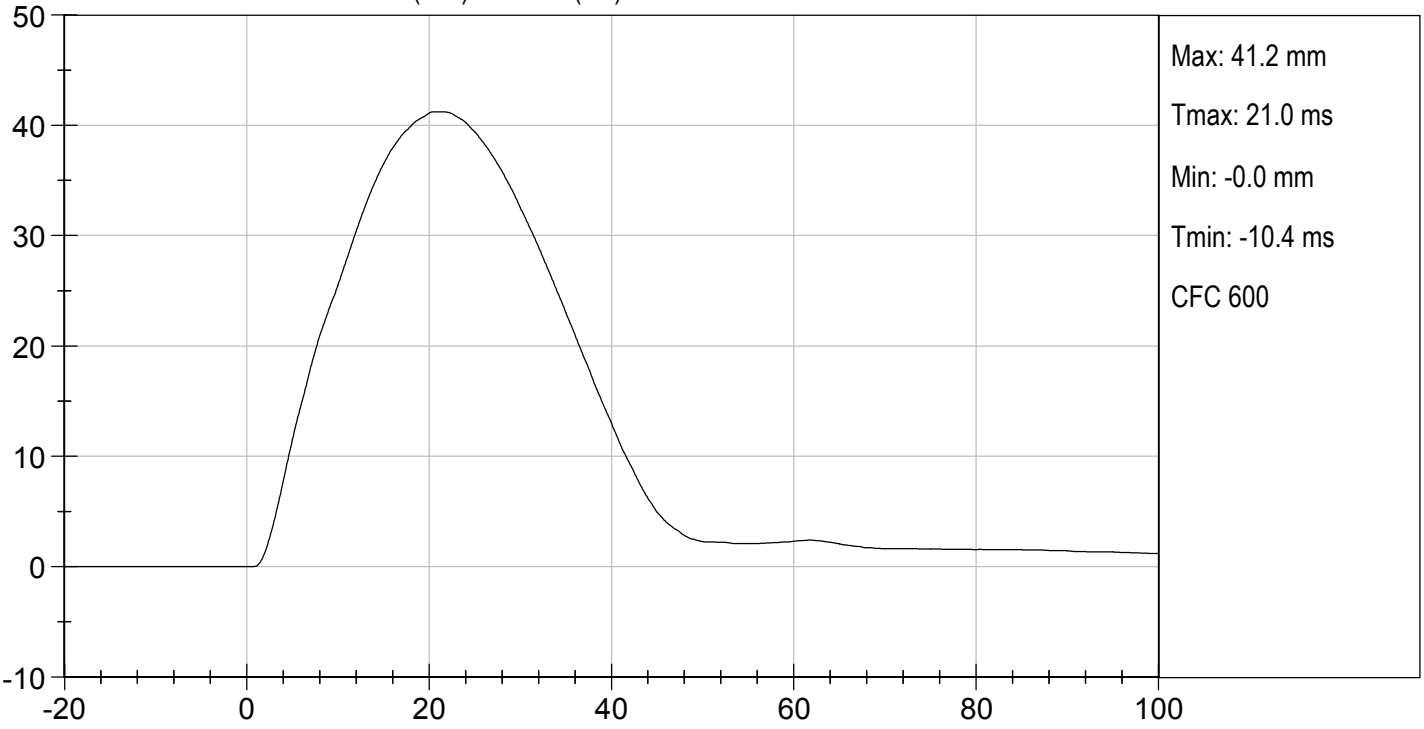
PROBE (G's) vs TIME (ms)



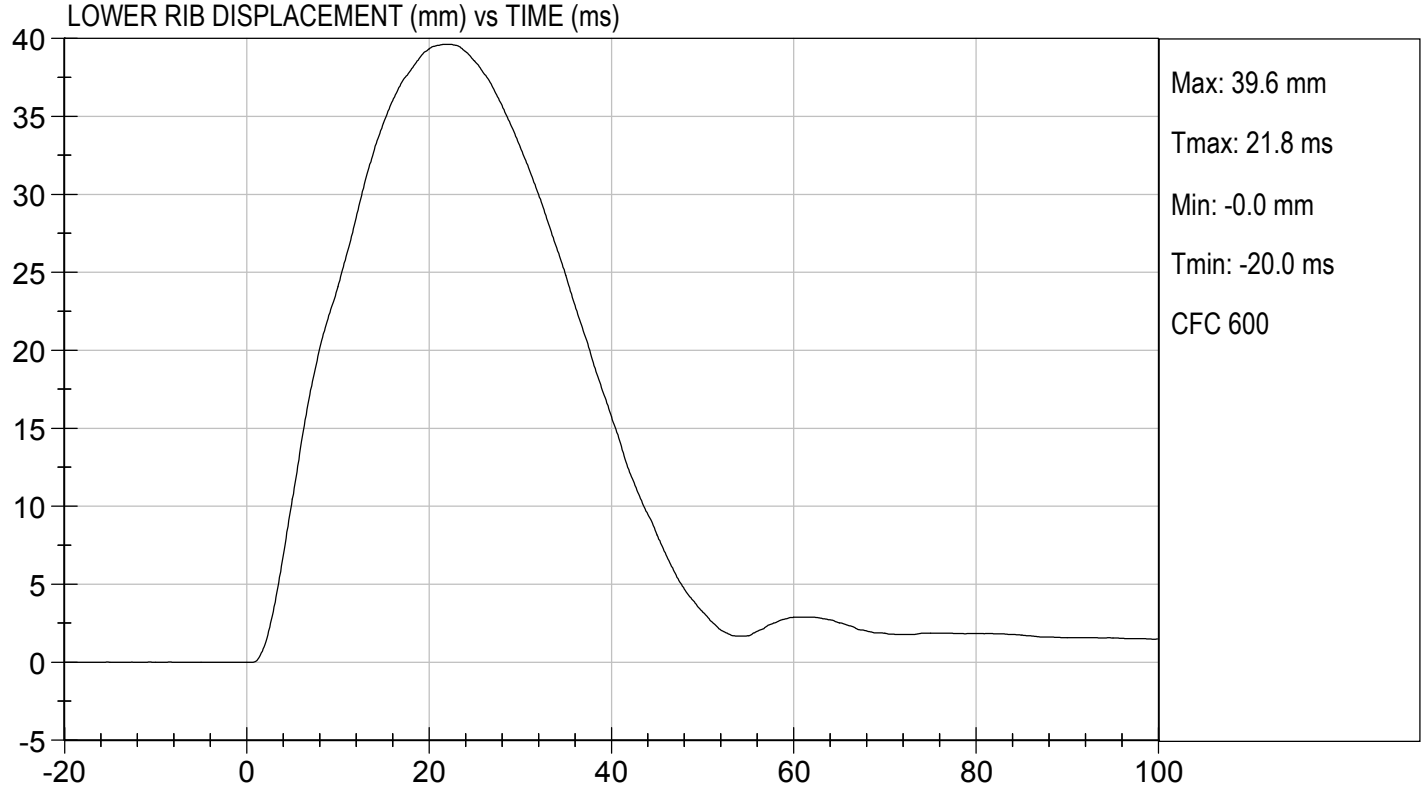
UPPER RIB DISPLACEMENT (mm) vs TIME (ms)



MIDDLE RIB DISPLACEMENT (mm) vs TIME (ms)



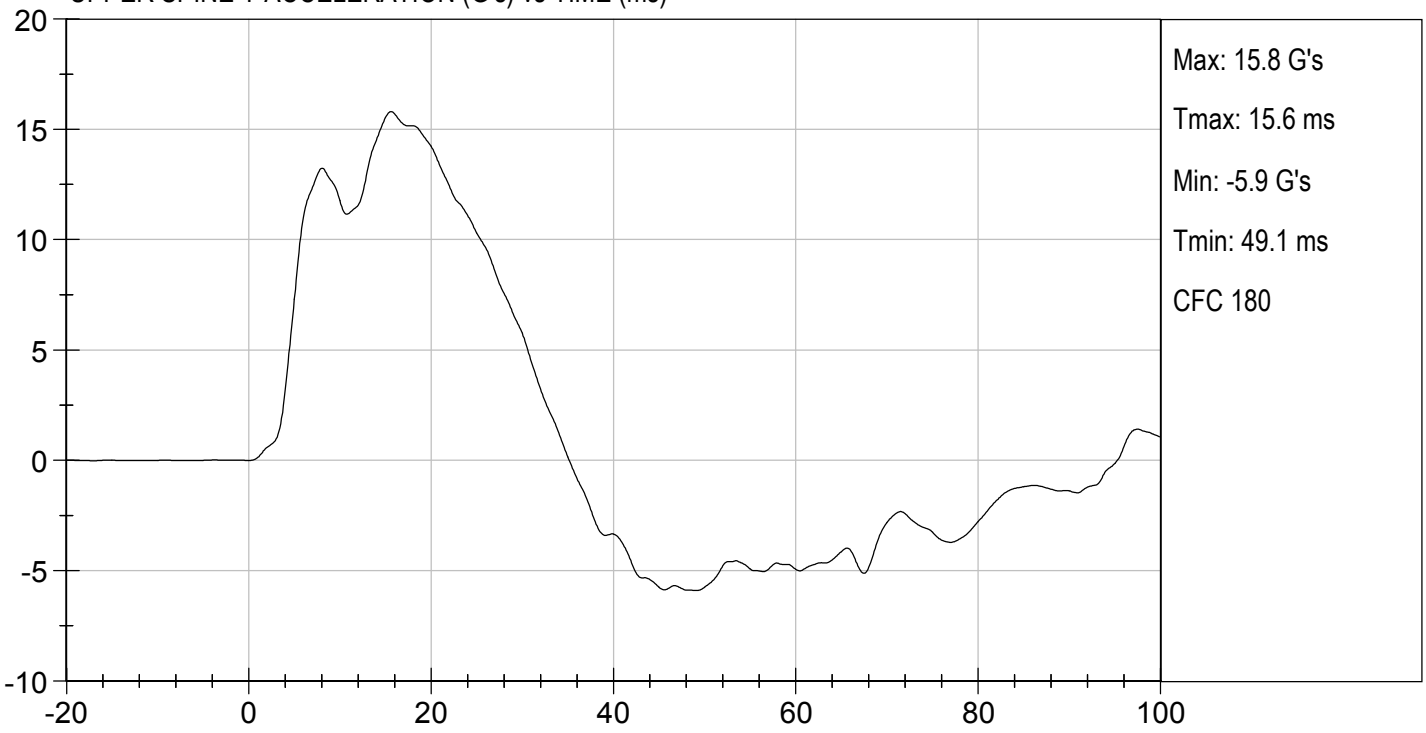
LOWER RIB DISPLACEMENT (mm) vs TIME (ms)



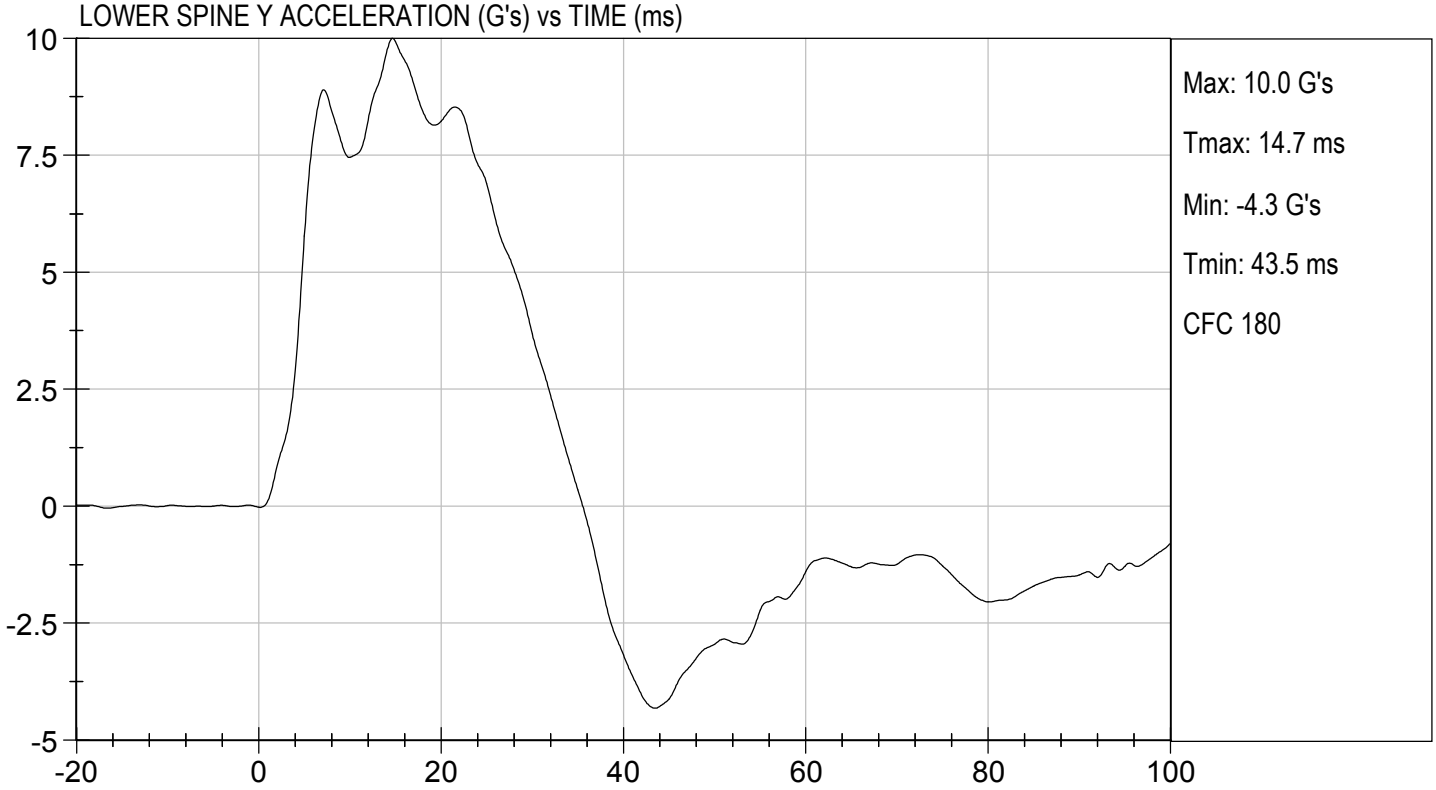
TEST DESC: THORAX IMPACT WITHOUT ARM
VELOCITY: 14.37 ft/s, 4.38 m/s

TEST DATE: 08/27/2018
TEST #: D182635

UPPER SPINE Y ACCELERATION (G's) vs TIME (ms)



LOWER SPINE Y ACCELERATION (G's) vs TIME (ms)



MGA RESEARCH CORPORATION

ABDOMINAL IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182636

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.6	Pass
Humidity	%	10 to 70	51	Pass
Impact Velocity	m/s	4.20 to 4.40	4.27	Pass
Maximum Probe Acceleration	G's	12 to 16	14	Pass
Upper Abdomen Rib Displacement	mm	36 to 47	40	Pass
Lower Abdomen Rib Displacement	mm	33 to 44	37	Pass
Lower Spine (T12) Y Acceleration	G's	9 to 14	11	Pass
		Overall Test Results		Pass

Danielle Redinbaugh
Laboratory Technician

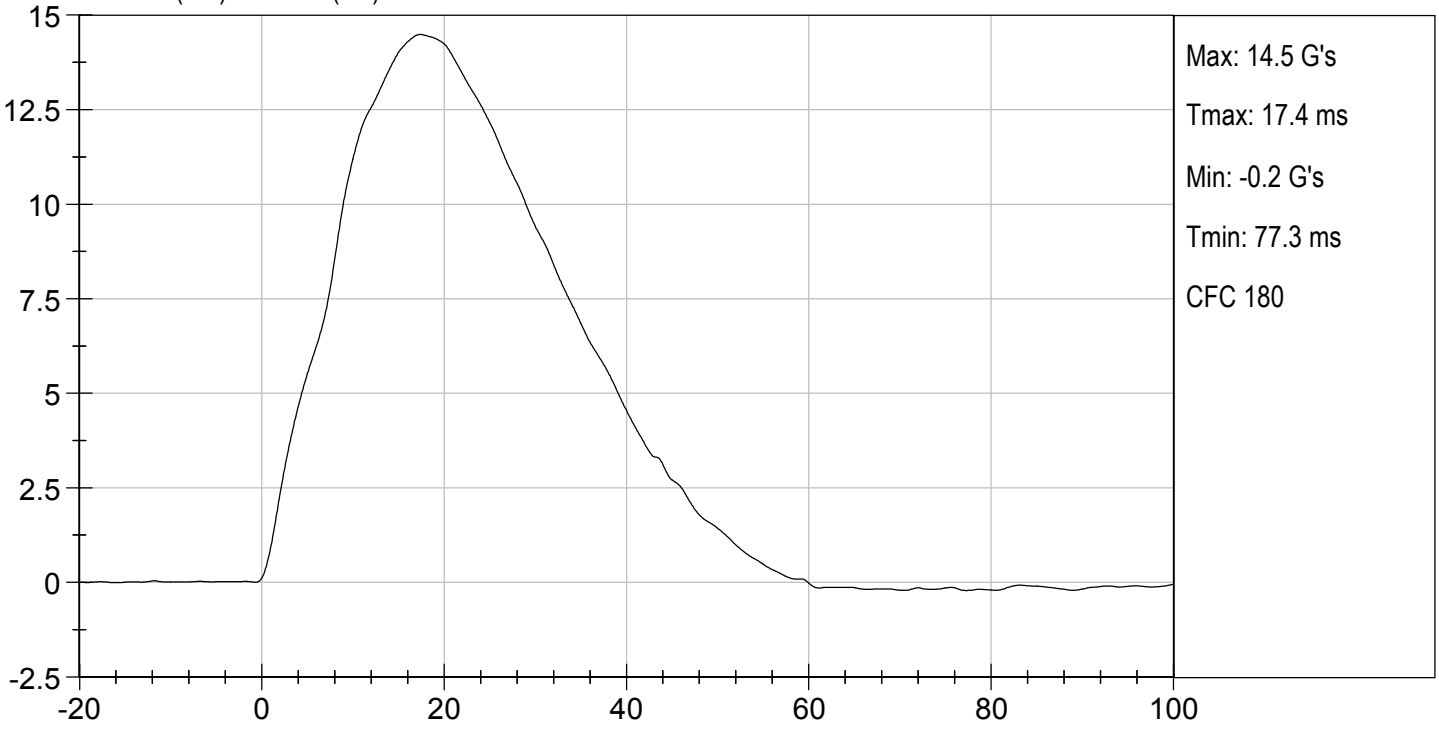
08/27/2018
Test Date

Approved By

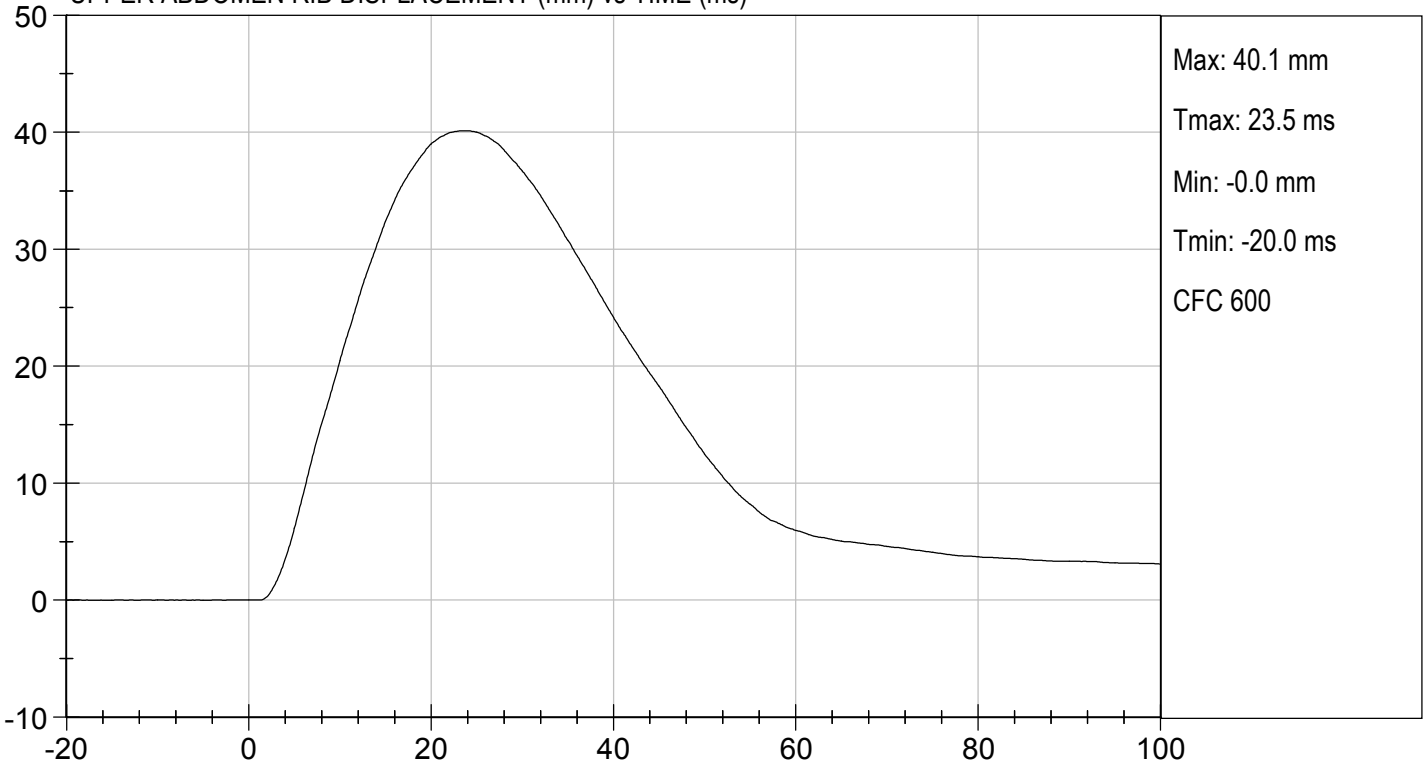
TEST DESC: ABDOMEN IMPACT
VELOCITY: 14.01 ft/s, 4.27 m/s

TEST DATE: 08/27/2018
TEST #: D182636

PROBE (G's) vs TIME (ms)



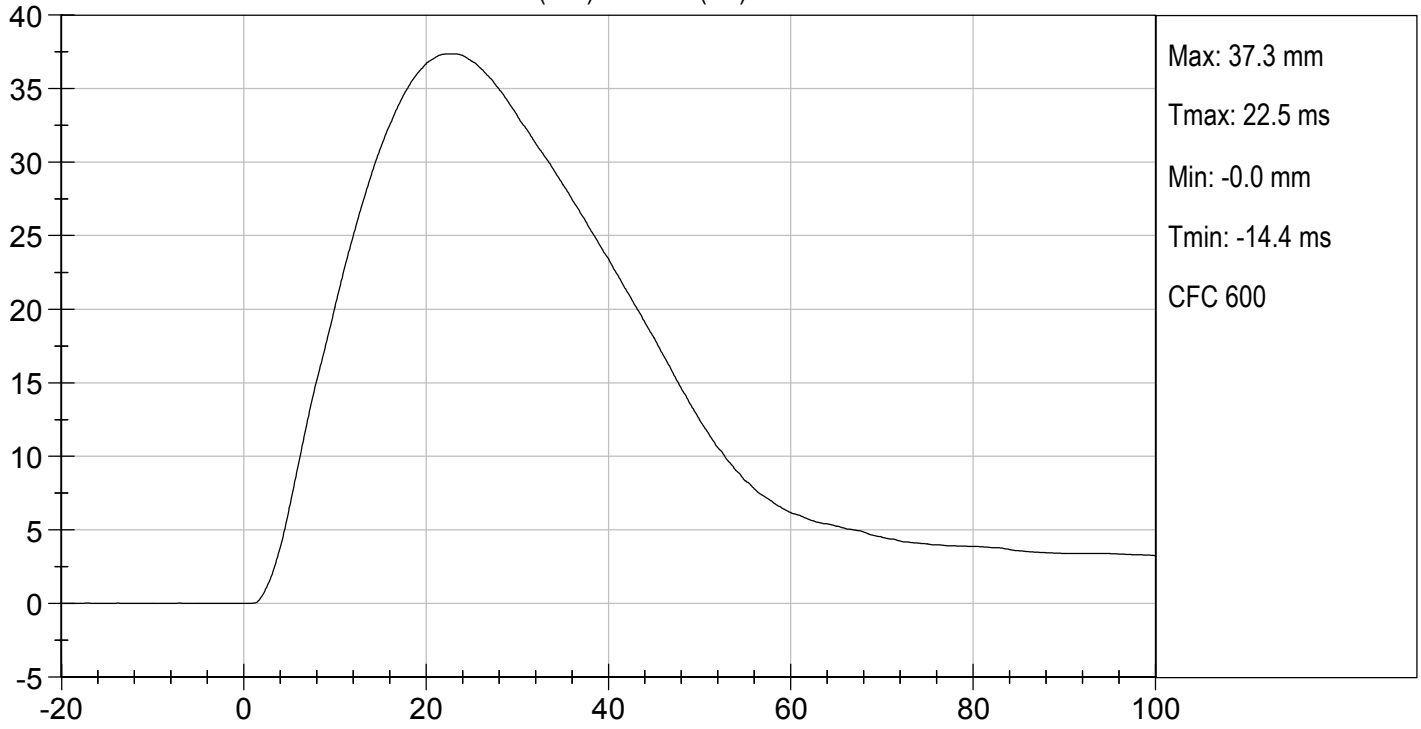
UPPER ABDOMEN RIB DISPLACEMENT (mm) vs TIME (ms)



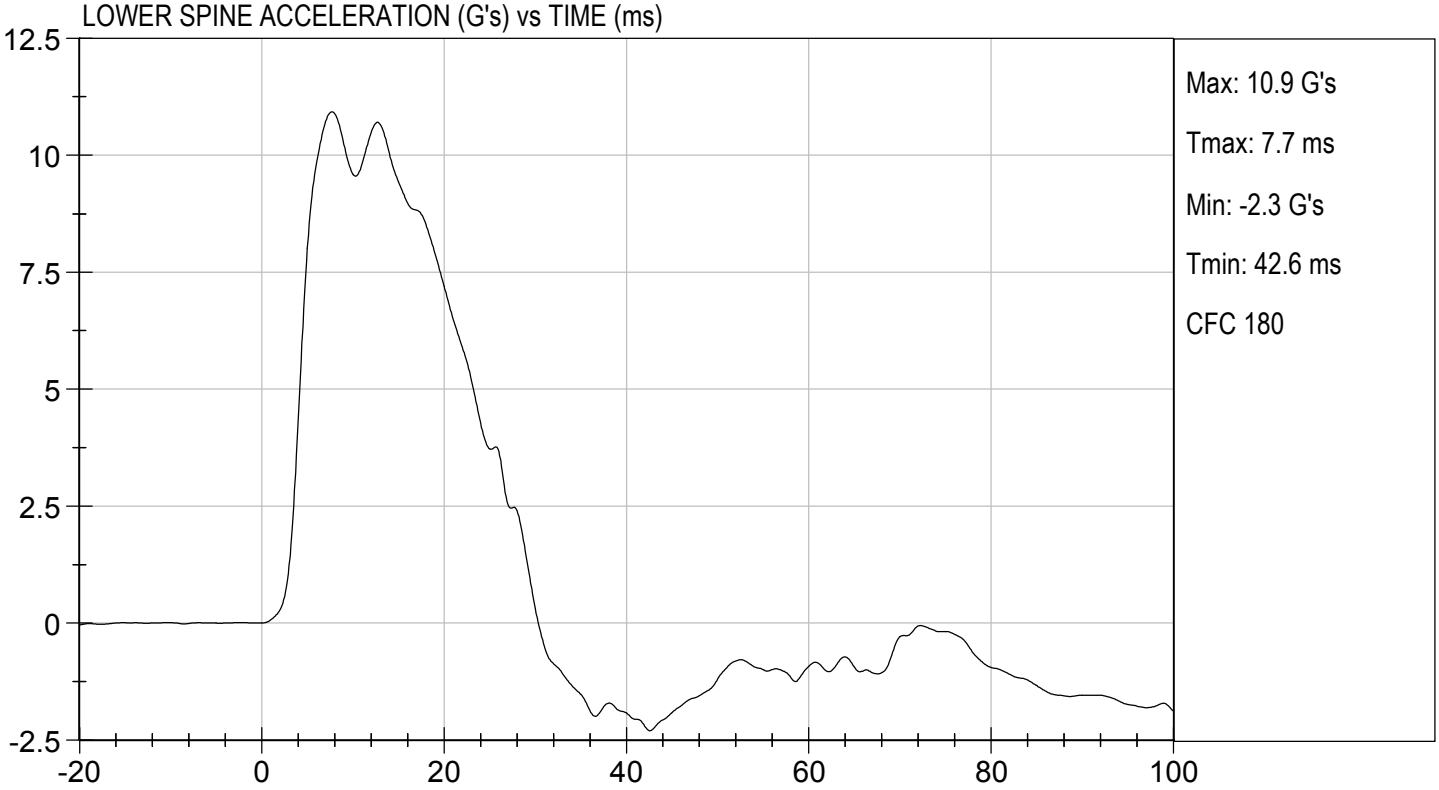
TEST DESC: ABDOMEN IMPACT
VELOCITY: 14.01 ft/s, 4.27 m/s

TEST DATE: 08/27/2018
TEST #: D182636

LOWER ABDOMEN RIB DISPLACEMENT (mm) vs TIME (ms)



LOWER SPINE ACCELERATION (G's) vs TIME (ms)



MGA RESEARCH CORPORATION

PELVIS IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182637

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.6	Pass
Humidity	%	10 to 70	51	Pass
Impact Velocity	m/s	6.60 to 6.80	6.61	Pass
Maximum Probe Acceleration	G's	38 to 47	46	Pass
Pelvis Y Acceleration After 6 ms	G's	34 to 42	42	Pass
Peak Acetabulum Force	N	3600 to 4300	4,085	Pass
		Overall Test Results		Pass

Danielle Redinbaugh
Laboratory Technician

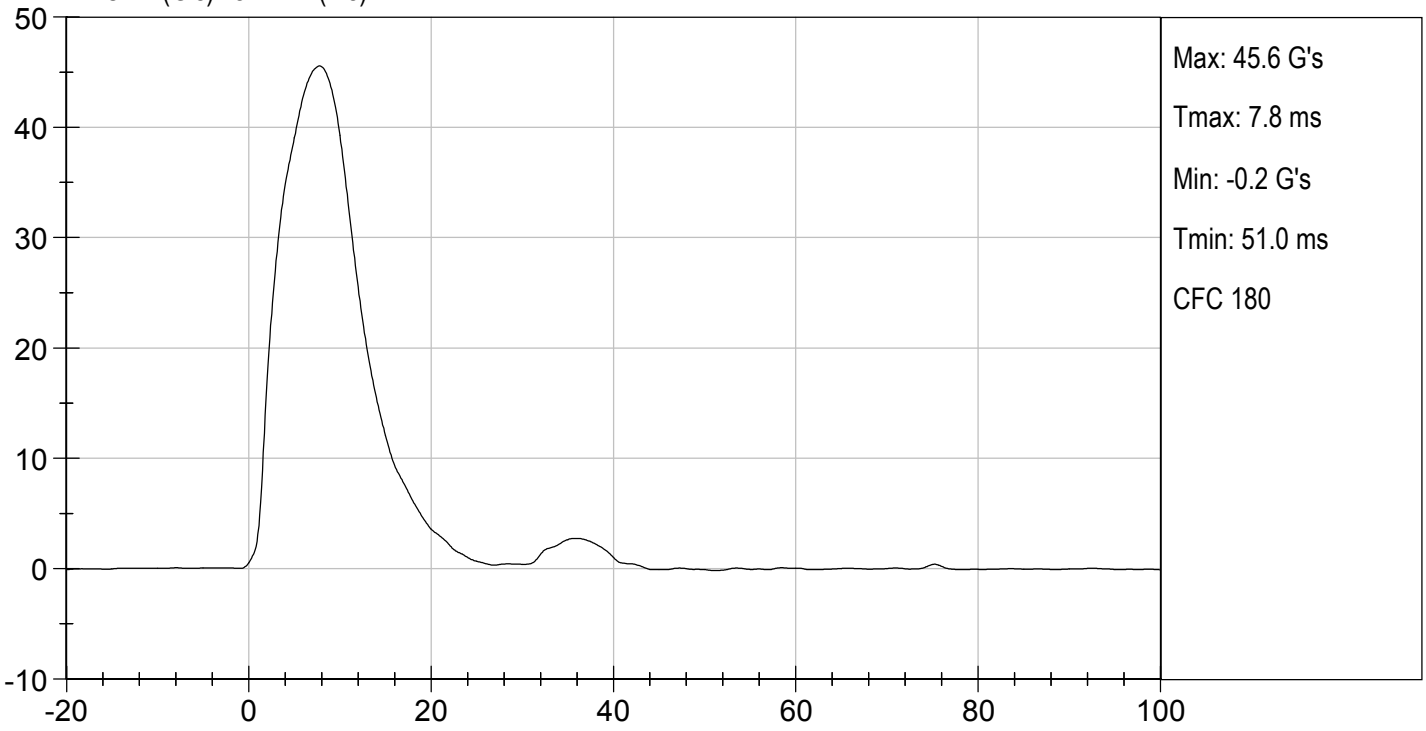
08/28/2018
Test Date

Approved By

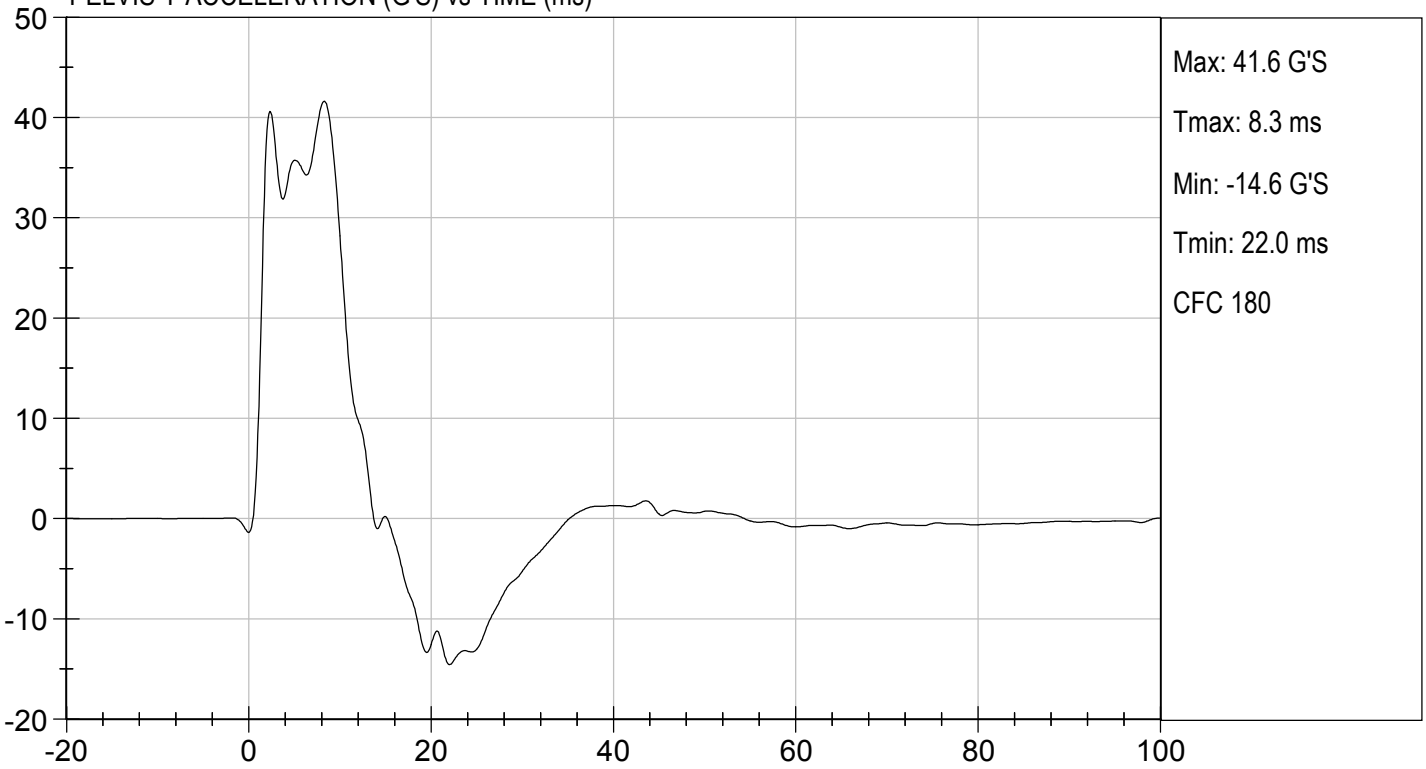
TEST DESC: PELVIS IMPACT
VELOCITY: 21.70 ft/s, 6.61 m/s

TEST DATE: 08/28/2018
TEST #: D182637

PROBE (G's) vs TIME (ms)

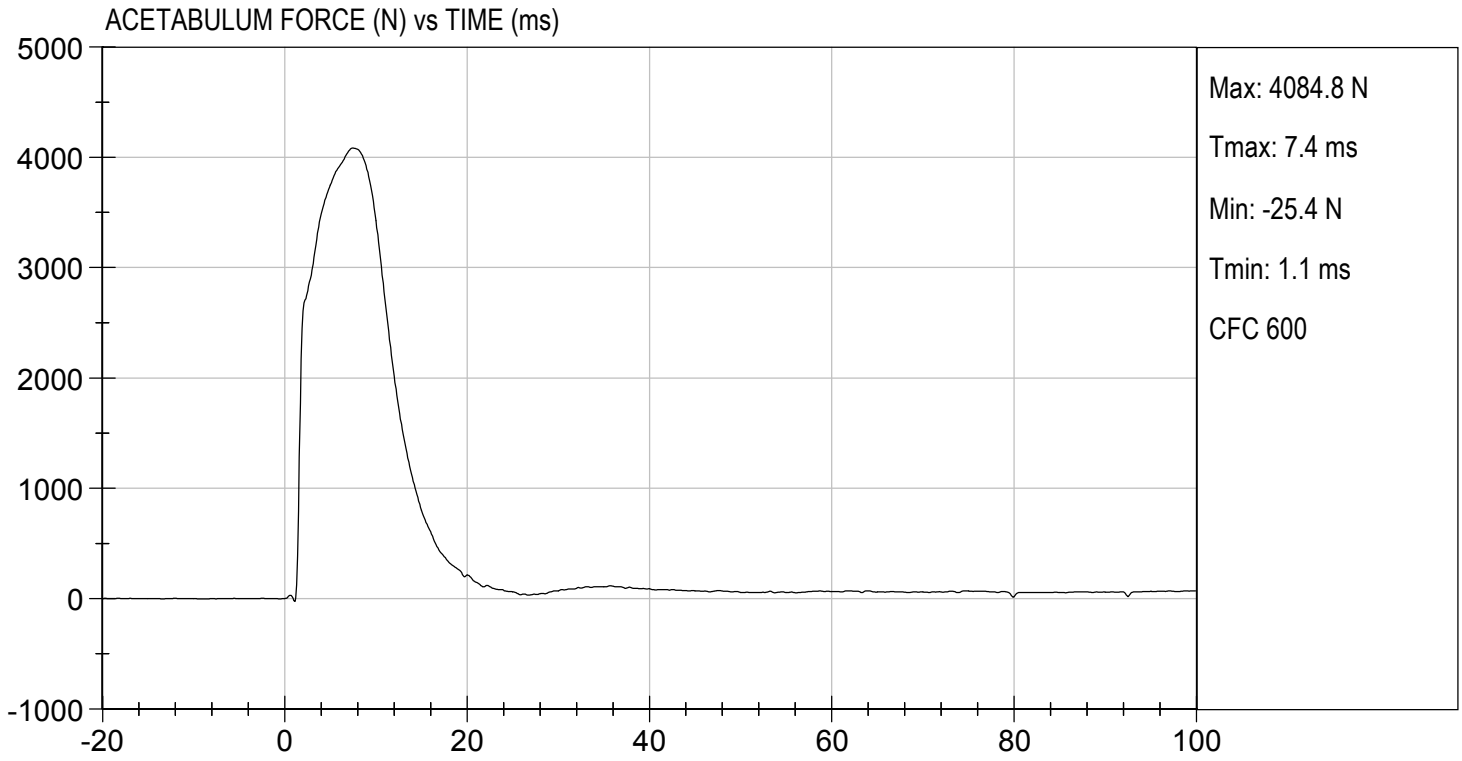


PELVIS Y ACCELERATION (G'S) vs TIME (ms)



TEST DESC: PELVIS IMPACT
VELOCITY: 21.70 ft/s, 6.61 m/s

TEST DATE: 08/28/2018
TEST #: D182637



MGA RESEARCH CORPORATION

ILIAC IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182638

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.6	Pass
Humidity	%	10 to 70	51	Pass
Impact Velocity	m/s	4.20 to 4.40	4.36	Pass
Maximum Probe Acceleration	G's	36 to 45	41	Pass
Pelvis Y Acceleration	G's	28 to 39	31	Pass
Peak Pelvis Iliac Force	N	4100 to 5100	4,762	Pass
		Overall Test Results		Pass

Danielle Redenbaugh
Laboratory Technician

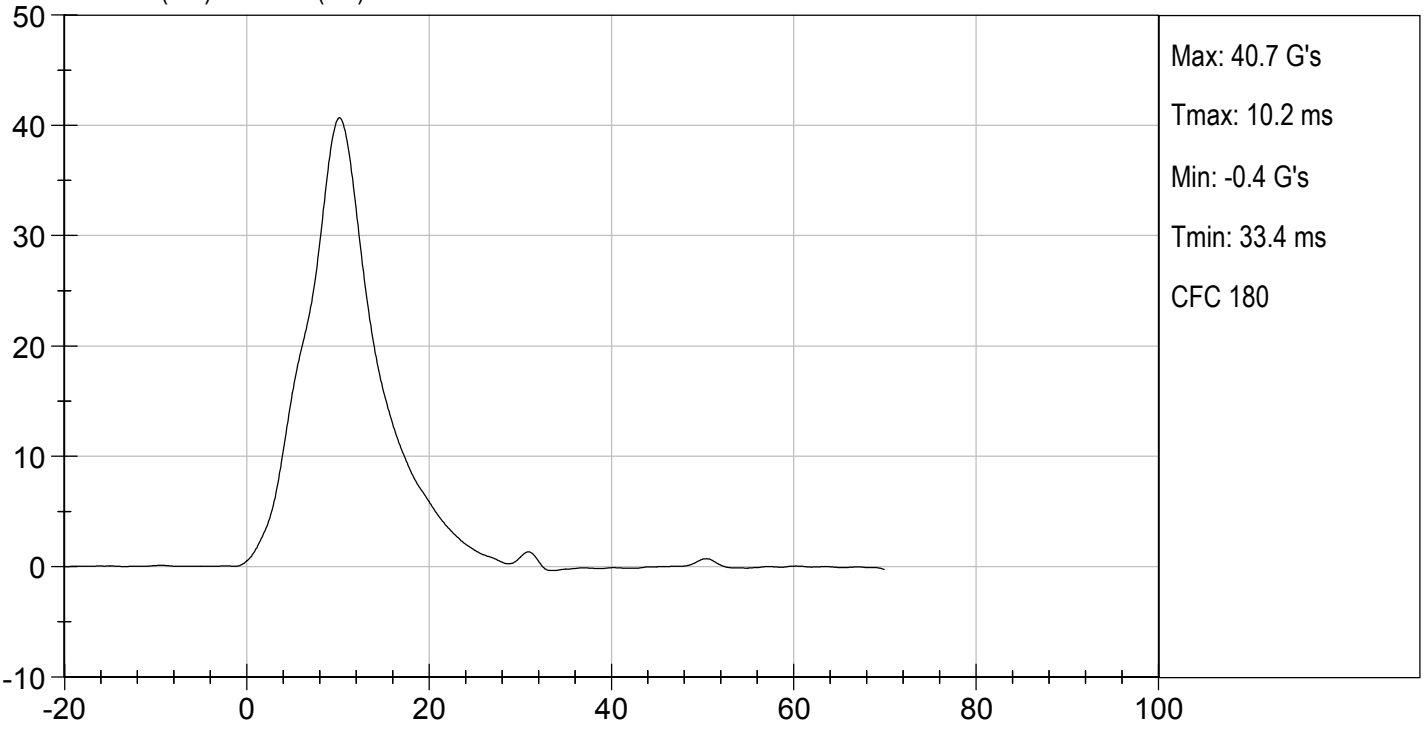
08/27/2018
Test Date

Approved By

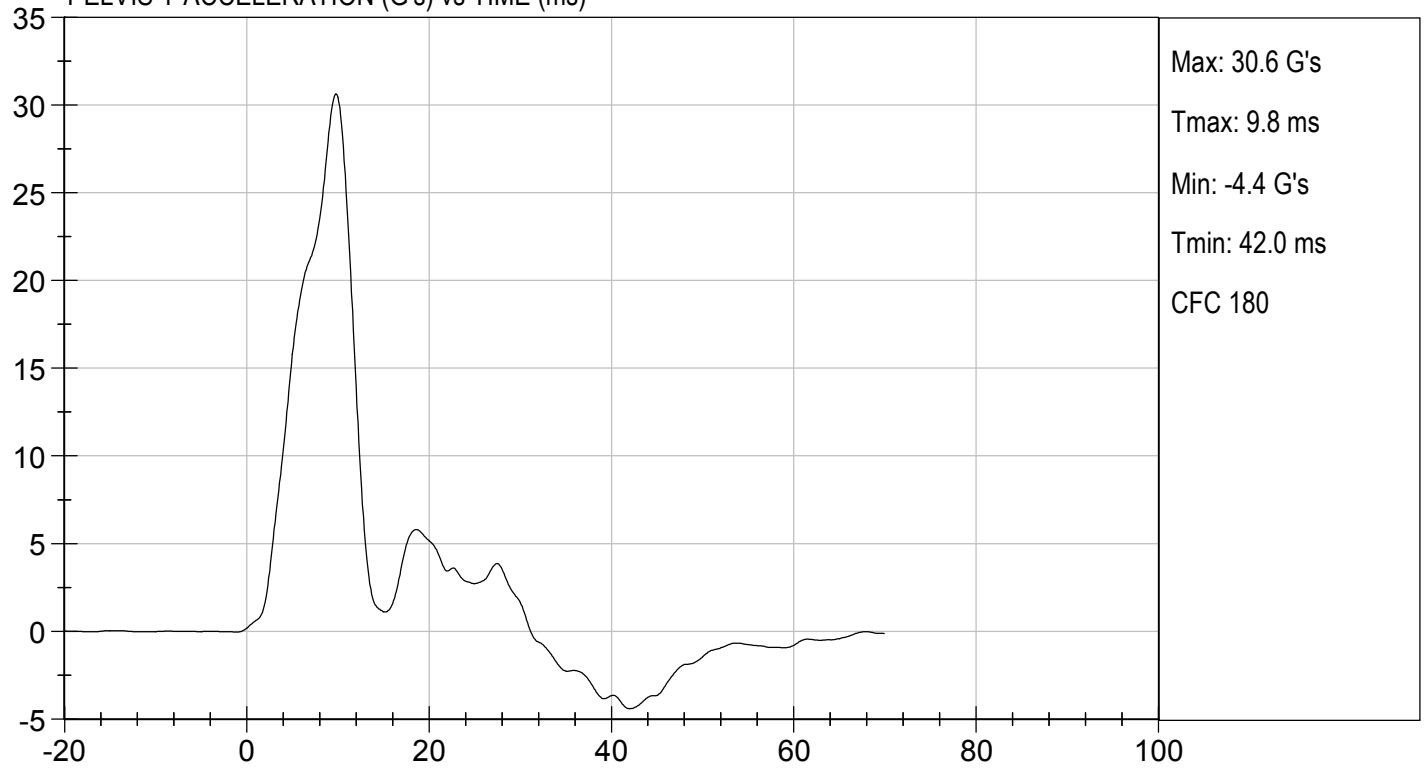
TEST DESC: ILLIAC
VELOCITY: 14.30 ft/s, 4.36 m/s

TEST DATE: 08/27/2018
TEST #: D182638

PROBE (G's) vs TIME (ms)

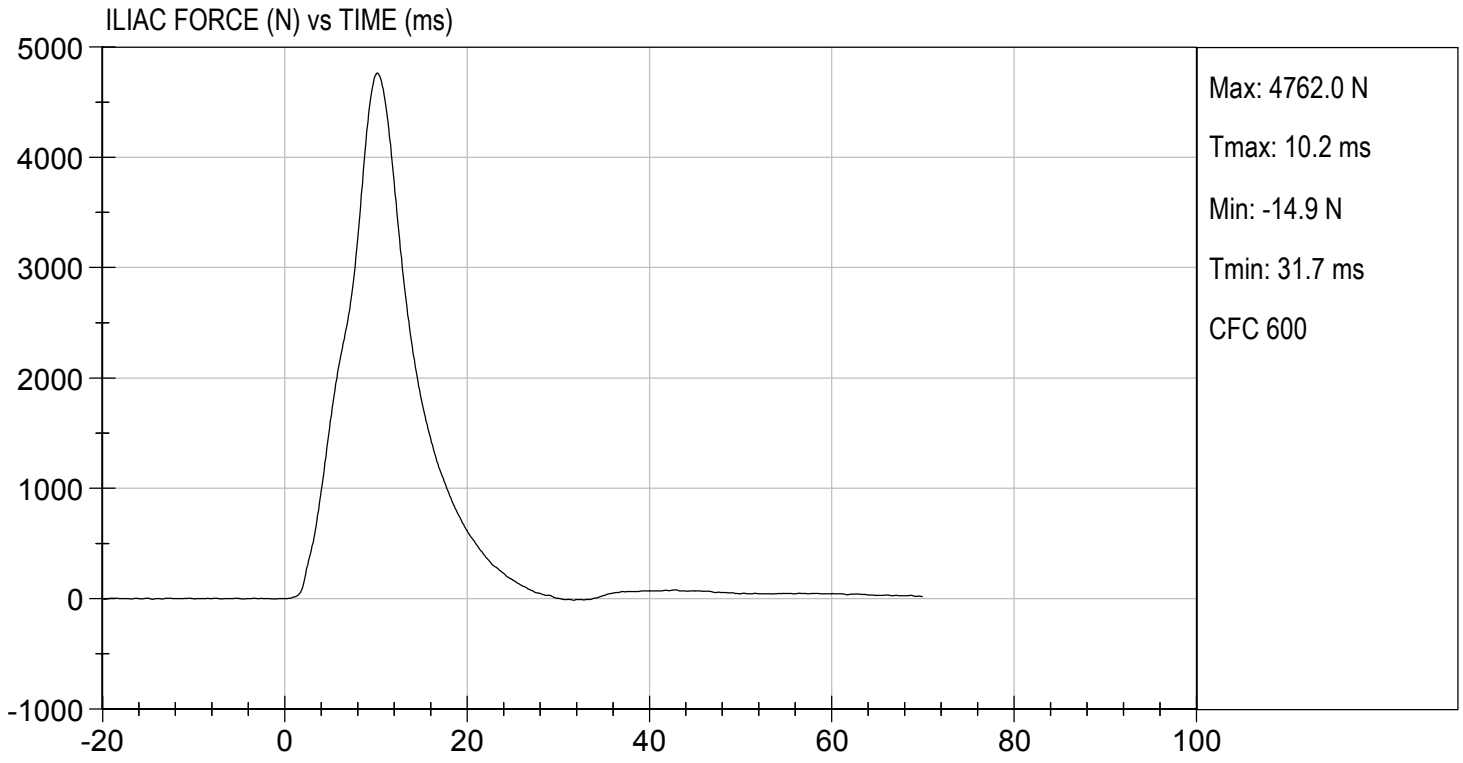


PELVIS Y ACCELERATION (G's) vs TIME (ms)



TEST DESC: ILLIAC
VELOCITY: 14.30 ft/s, 4.36 m/s

TEST DATE: 08/27/2018
TEST #: D182638



CALIBRATION TEST RESULTS

POST-TEST

SID-IIs ATD

MGA RESEARCH CORPORATION

HEAD DROP TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test ID:** D182961

Tested Parameter	Units	Specification	Result	Pass/Fail
Laboratory Temperature	deg C	20.6 to 22.2	22	Pass
Laboratory Relative Humidity	%	10 to 70	48	Pass
Peak Resultant Acceleration	G's	115 to 137	128	Pass
Peak Longitudinal Acceleration	G's	+/- 15	8.1	Pass
Unimodal	N/A	Yes	Yes	Pass
Oscillations	N/A	<15%	Yes	Pass
		Overall Test Results		Pass

Jacob D Taylor
Laboratory Technician

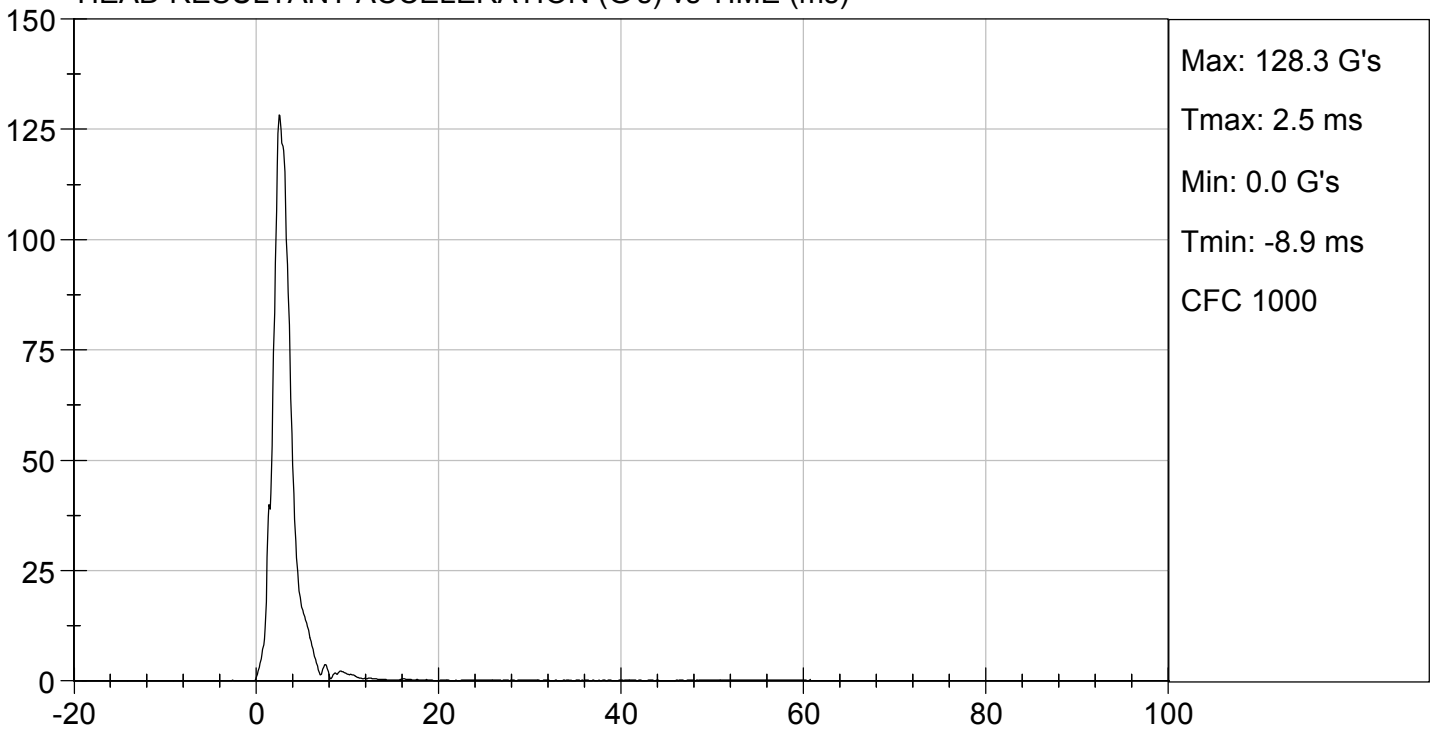
10/01/2018
Test Date

Approved By

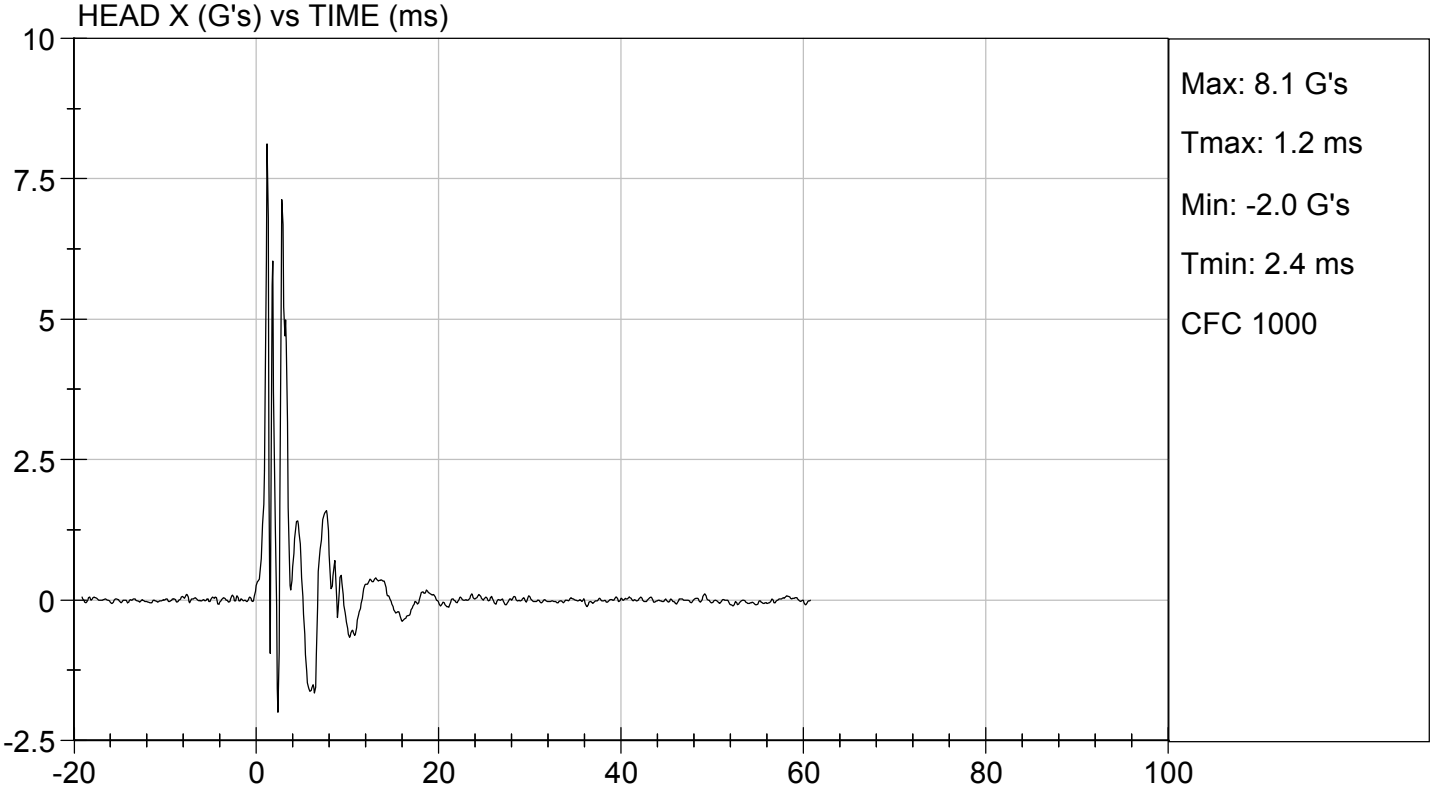
TEST DESC: HEAD DROP

TEST DATE: 10/01/2018
TEST #: D182961

HEAD RESULTANT ACCELERATION (G's) vs TIME (ms)

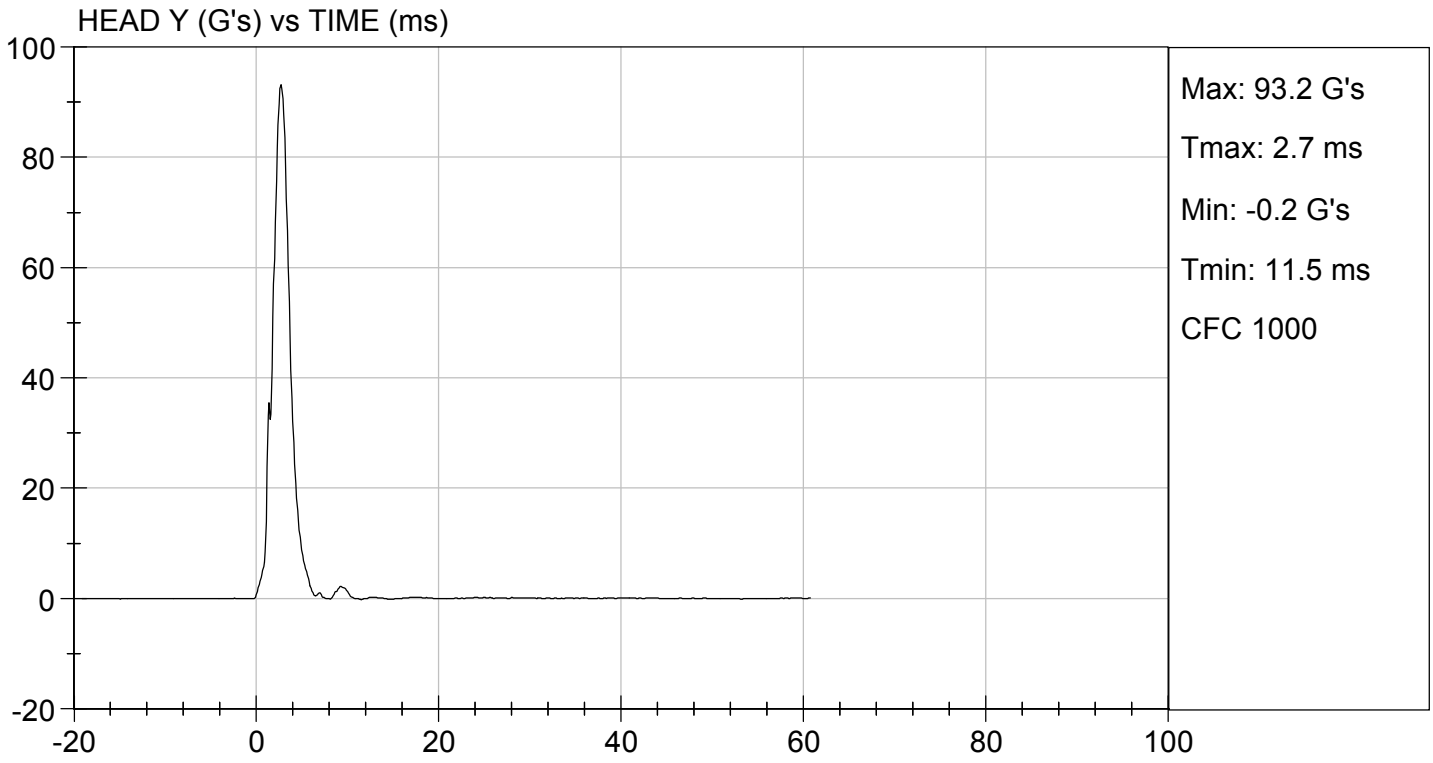


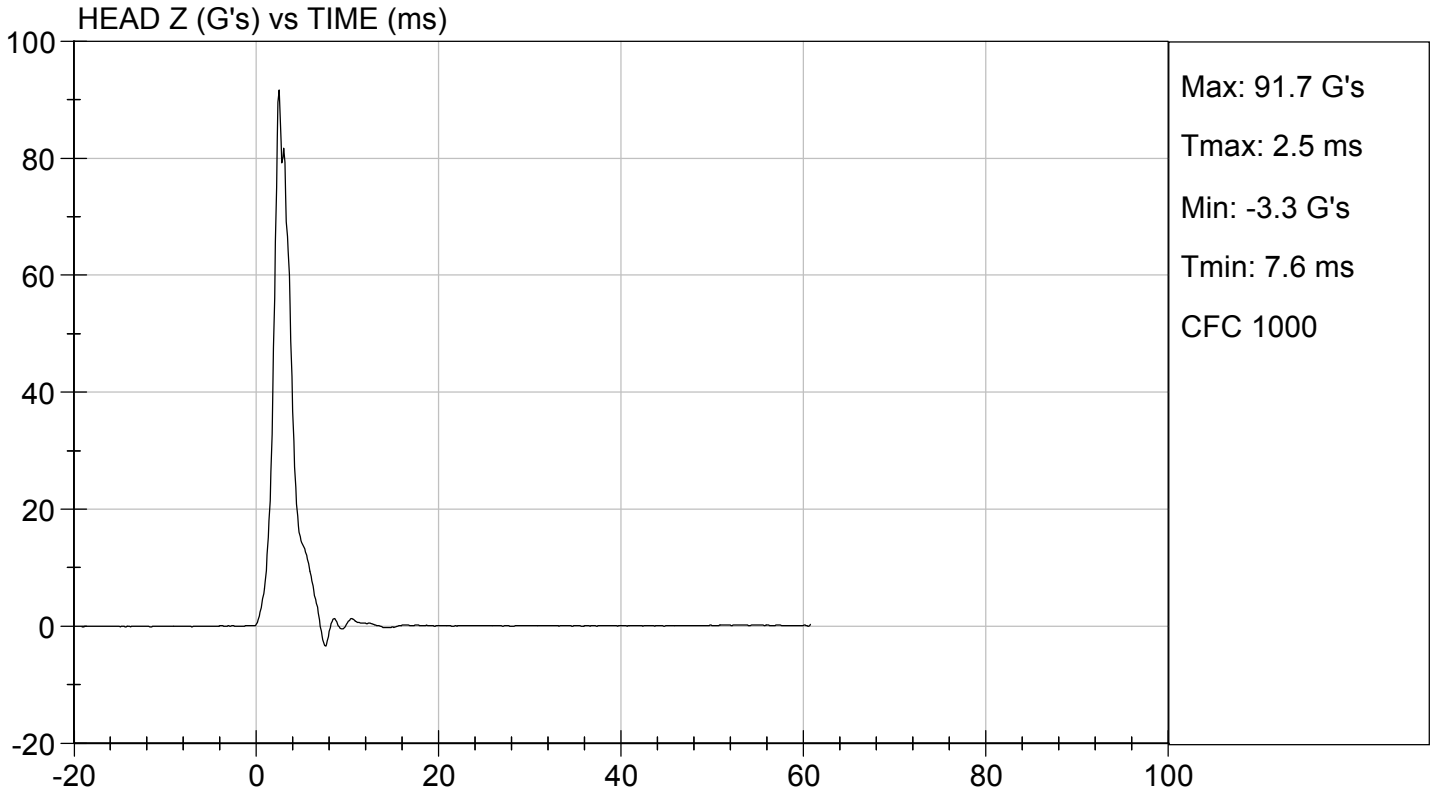
HEAD X (G's) vs TIME (ms)



TEST DESC: HEAD DROP

TEST DATE: 10/01/2018
TEST #: D182961





MGA RESEARCH CORPORATION

LATERAL NECK PENDULUM TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182962

Tested Parameter		Units	Specification	Result	Pass/Fail
Temperature		deg C	20.6 to 22.2	22	Pass
Humidity		%	10 to 70	48	Pass
Impact Velocity		m/s	5.51 to 5.63	5.52	Pass
Pendulum Velocity	10 ms	m/s	2.20 to 2.80	2.66	Pass
	15 ms	m/s	3.30 to 4.10	3.90	Pass
	20 ms	m/s	4.40 to 5.40	5.35	Pass
	25 ms	m/s	5.40 to 6.10	5.63	Pass
	25-100 ms	m/s	5.50 to 6.20	5.66	Pass
Maximum D-Plane Rotation		deg	71 to 81	78	Pass
Time of Maximum D-Plane Rotation		ms	50 to 70	63	Pass
Maximum Occipital Condyle Moment		Nm	-44 to -36	-41	Pass
Time of Moment Decay to 0 Nm		ms	102 to 126	116	Pass
			Overall Test Results		Pass

Jacob D Taylor

Laboratory Technician

10/01/2018

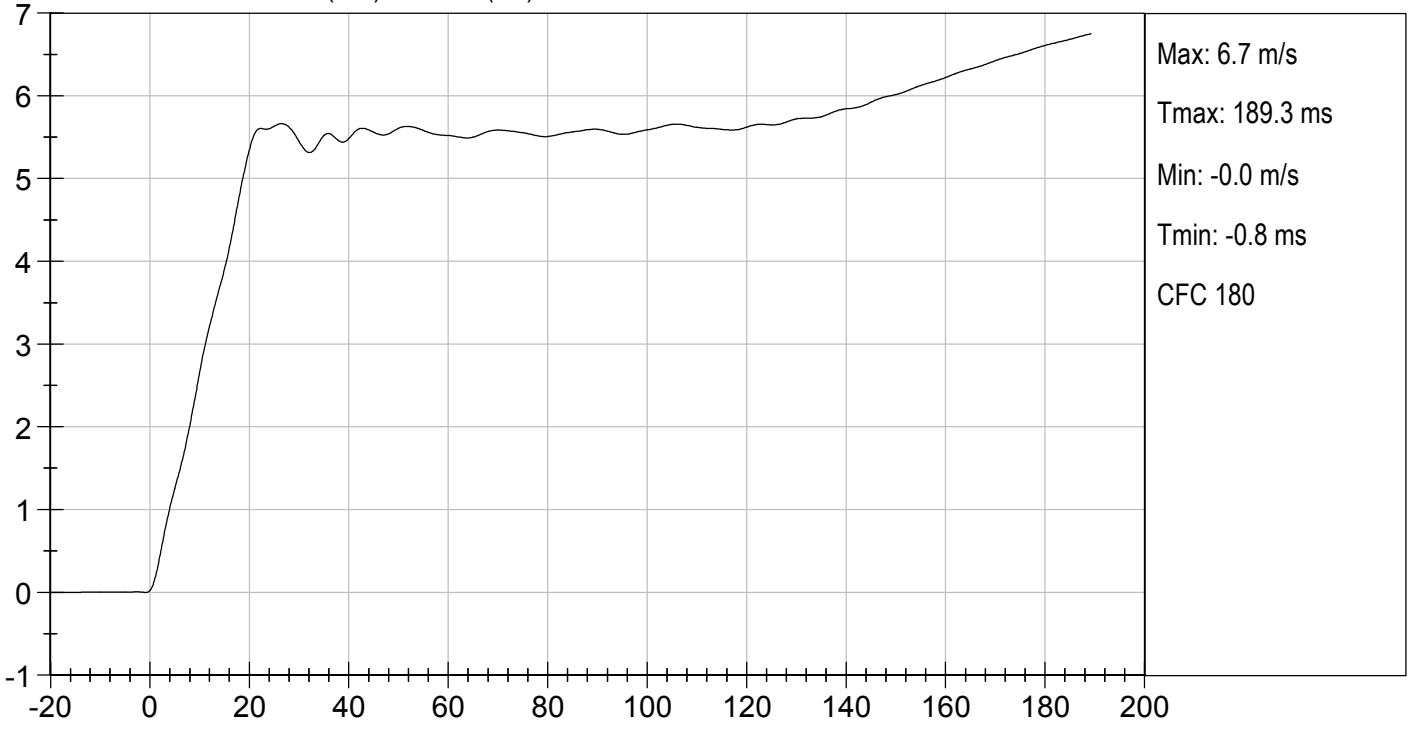
Test Date

Approved By

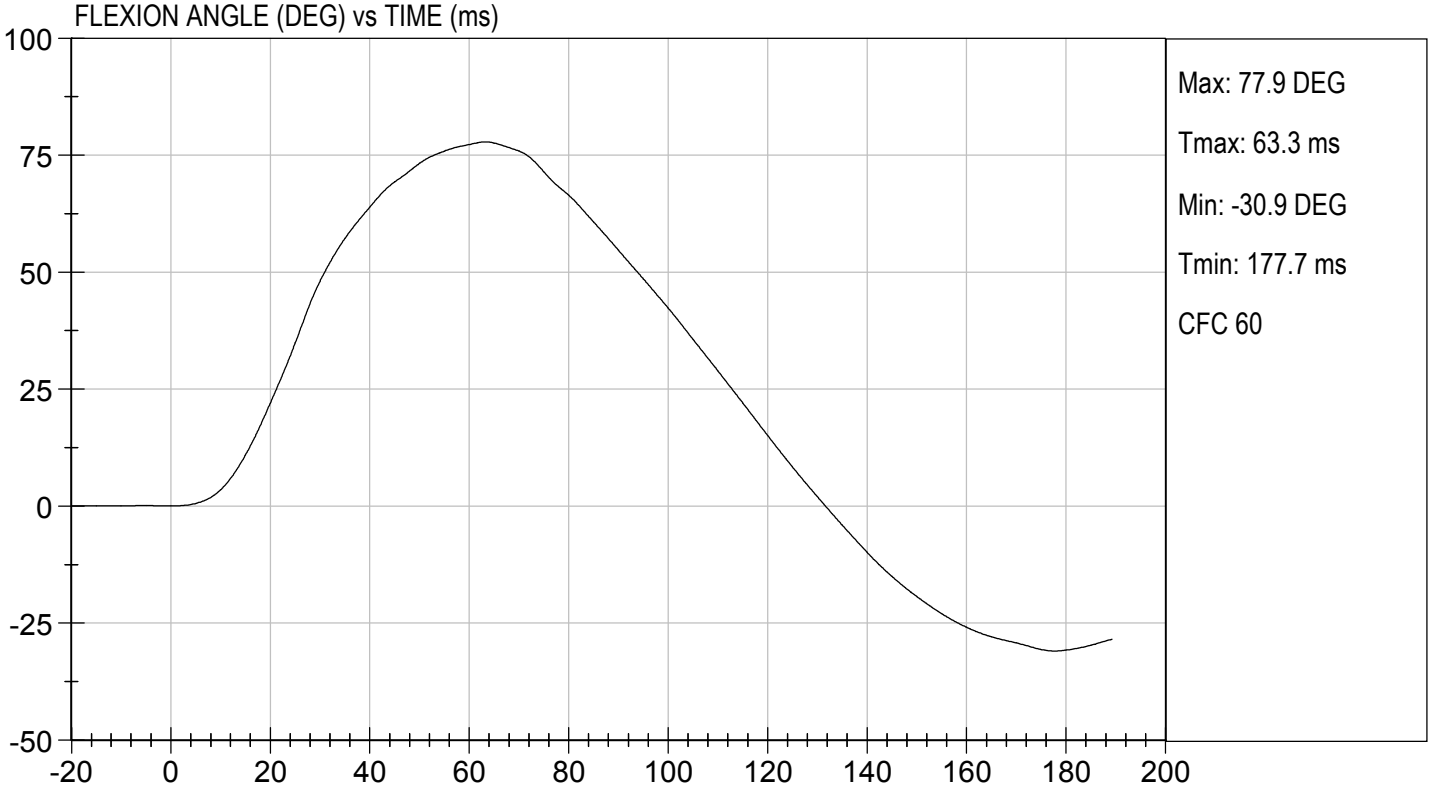
TEST DESC: NECK BENDING
VELOCITY: 18.12 ft/s, 5.52 m/s

TEST DATE: 10/01/2018
TEST #: D182962

PENDULUM VELOCITY (m/s) vs TIME (ms)

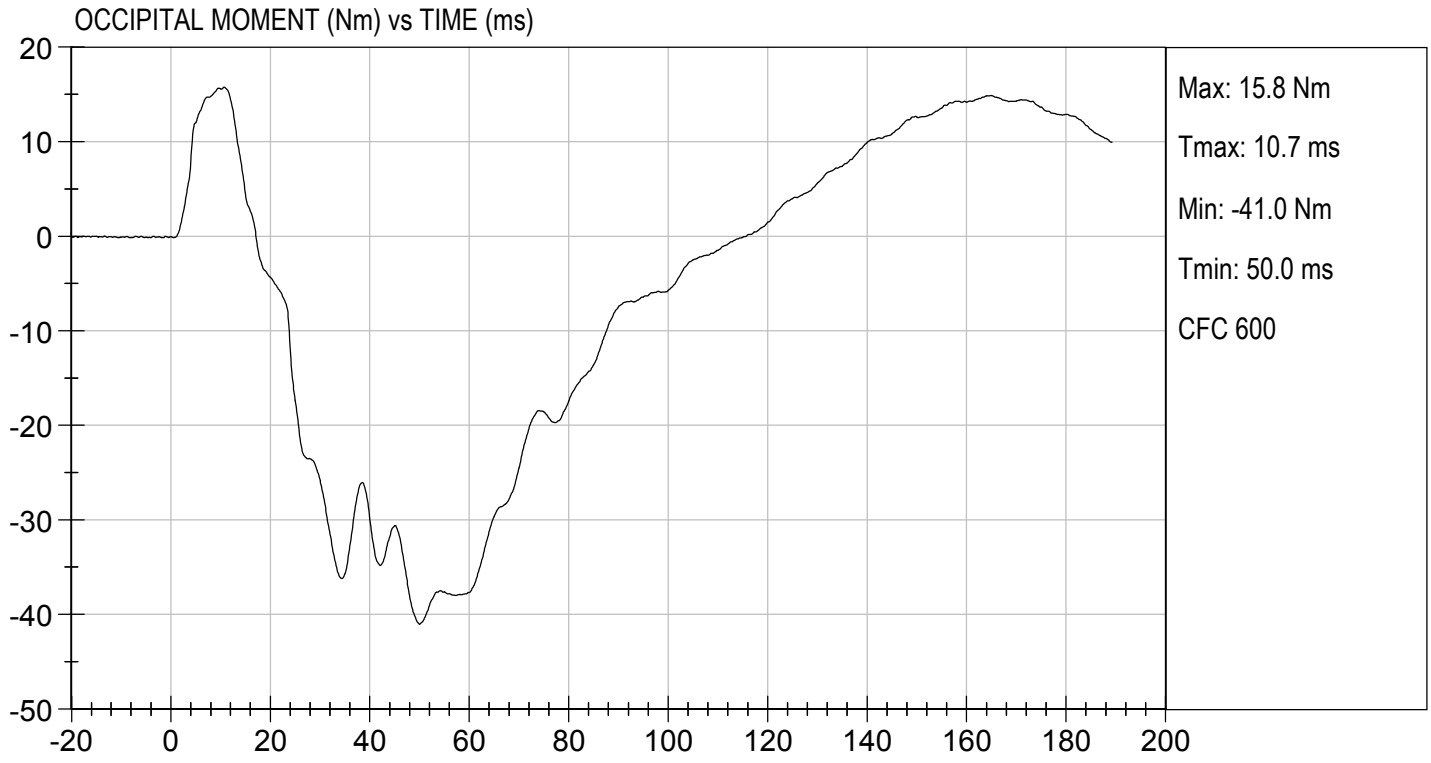


FLEXION ANGLE (DEG) vs TIME (ms)



TEST DESC: NECK BENDING
VELOCITY: 18.12 ft/s, 5.52 m/s

TEST DATE: 10/01/2018
TEST #: D182962



MGA RESEARCH CORPORATION

SHOULDER IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test ID:** D181963

Tested Parameter	Units	Specification	Result	Pass/Fail
Laboratory Temperature	deg C	20.6 to 22.2	21.3	Pass
Laboratory Relative Humidity	%	10 to 70	39	Pass
Impact Velocity	m/s	4.20 to 4.40	4.23	Pass
Maximum Probe Acceleration	G's	13 to 18	15	Pass
Shoulder Displacement	mm	28 to 37	31	Pass
Upper Spine (T1) Y Acceleration	G's	17 to 22	18	Pass
		Overall Test Results		Pass

Jacob D Taylor
Laboratory Technician

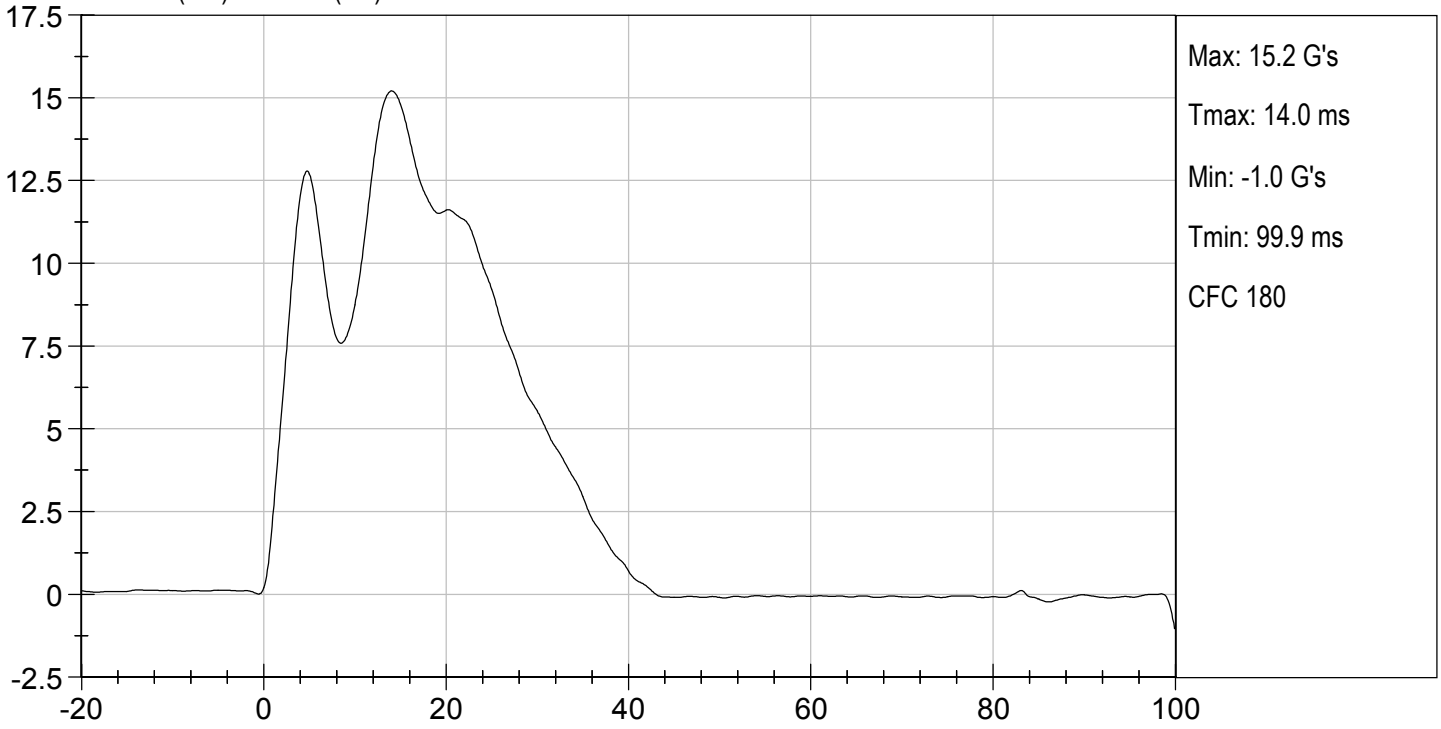
10/04/2018
Test Date

Approved By

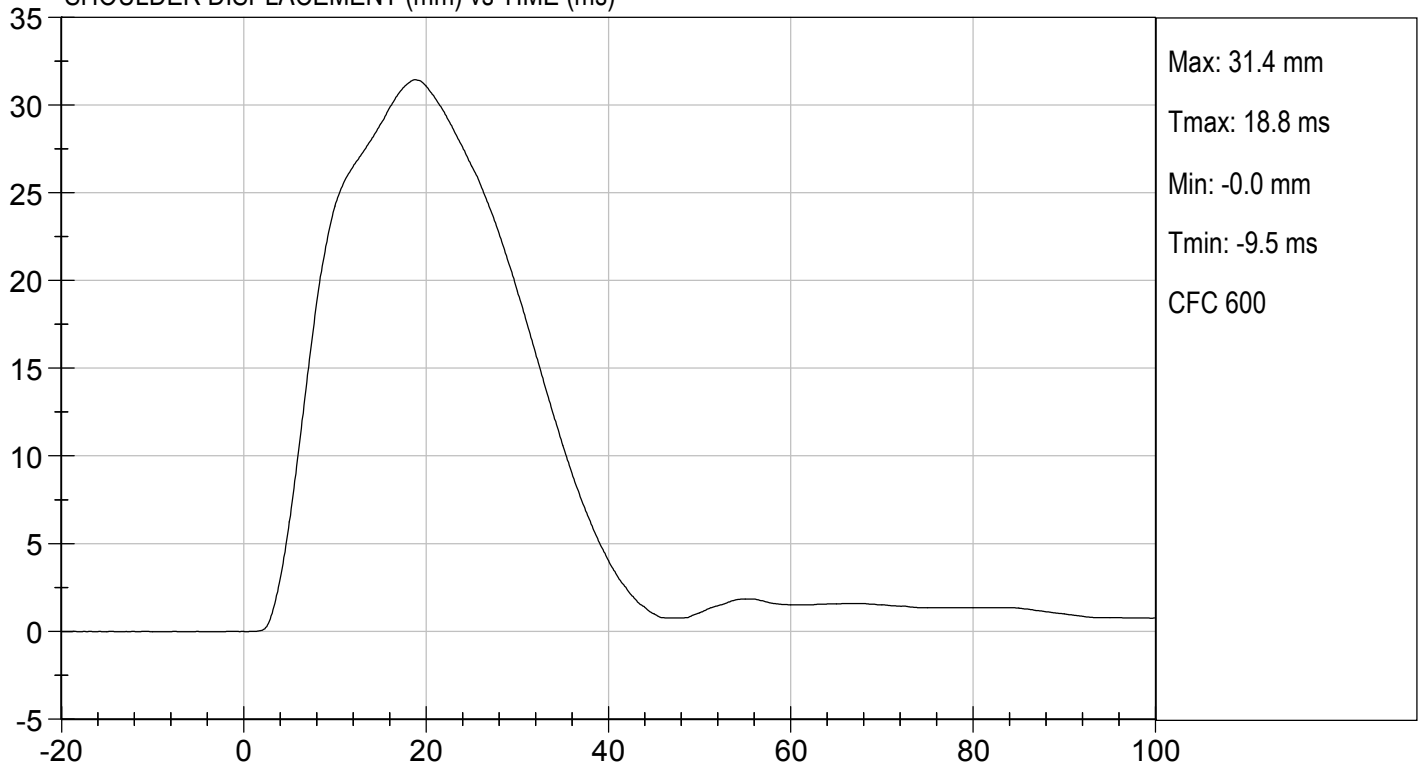
TEST DESC: SHOULDER IMPACT
VELOCITY: 13.88 ft/s, 4.23 m/s

TEST DATE: 10/04/2018
TEST #: D181963

PROBE (G's) vs TIME (ms)

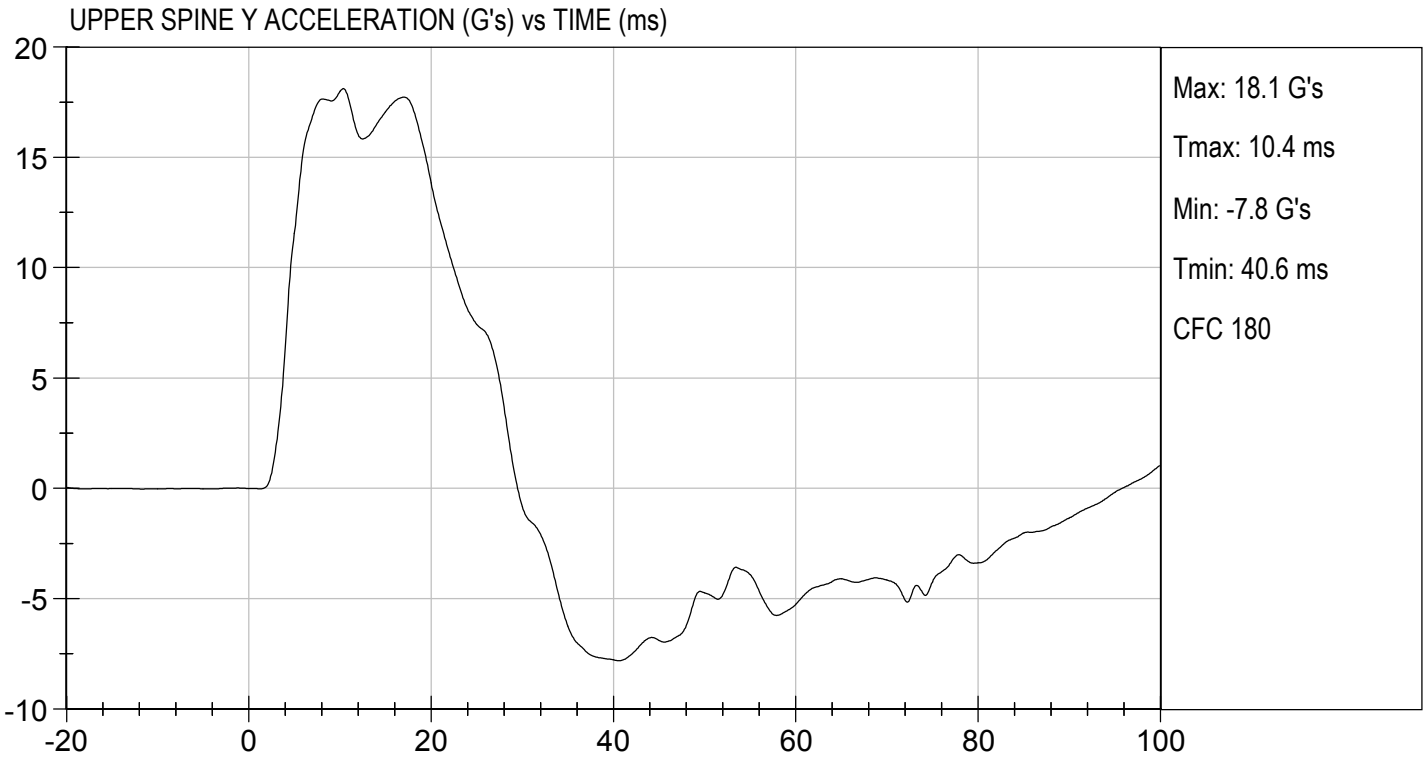


SHOULDER DISPLACEMENT (mm) vs TIME (ms)



TEST DESC: SHOULDER IMPACT
VELOCITY: 13.88 ft/s, 4.23 m/s

TEST DATE: 10/04/2018
TEST #: D181963



MGA RESEARCH CORPORATION

THORAX (WITH ARM) IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182964

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.3	Pass
Humidity	%	10 to 70	39	Pass
Impact Velocity	m/s	6.60 to 6.80	6.60	Pass
Maximum Probe Acceleration	G's	30 to 36	33	Pass
Shoulder Displacement	mm	31 to 40	36	Pass
Upper Rib Displacement	mm	25 to 32	28	Pass
Middle Rib Displacement	mm	30 to 36	32	Pass
Lower Rib Displacement	mm	32 to 38	33	Pass
Upper Spine (T1) Y Acceleration	G's	34 to 43	39	Pass
Lower Spine (T12) Y Acceleration	G's	29 to 37	32	Pass
		Overall Test Results		Pass

Jacob D Taylor

Laboratory Technician

10/04/2018

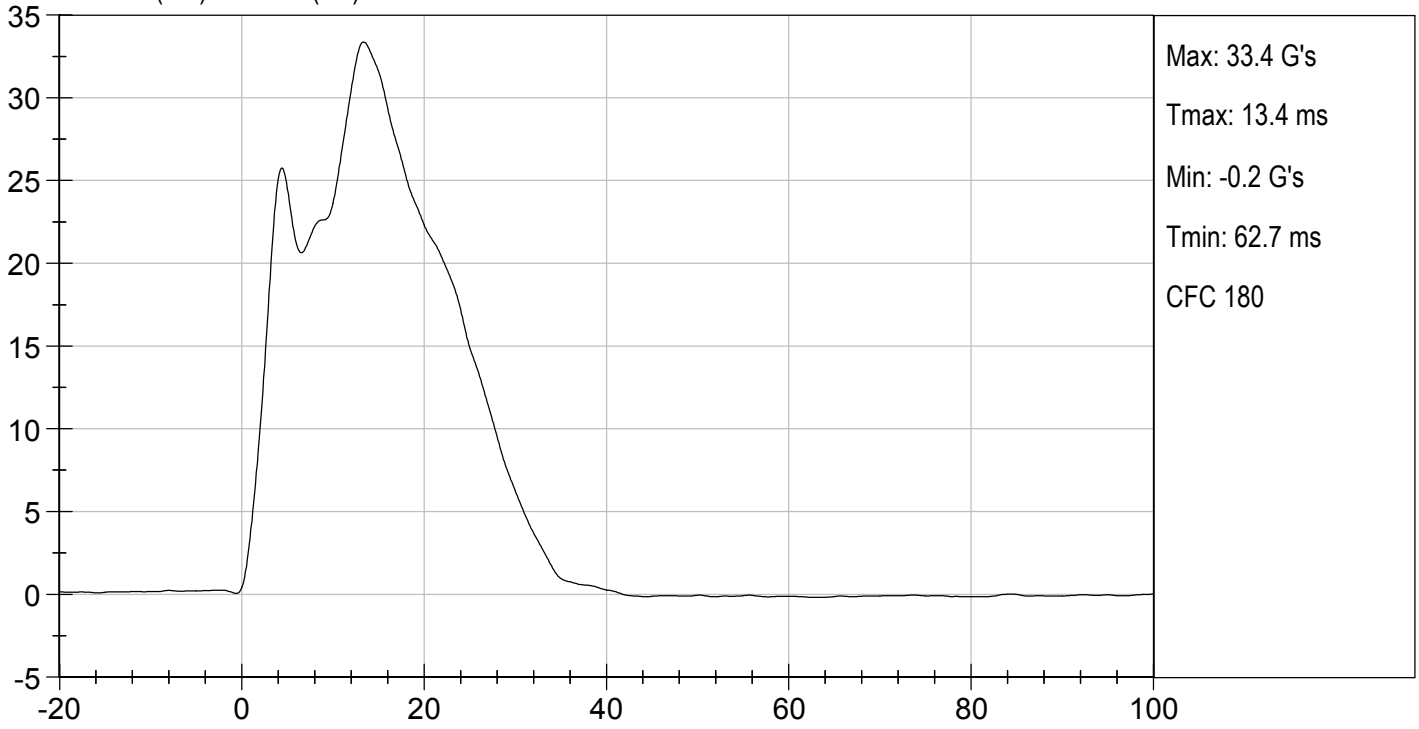
Test Date

Approved By

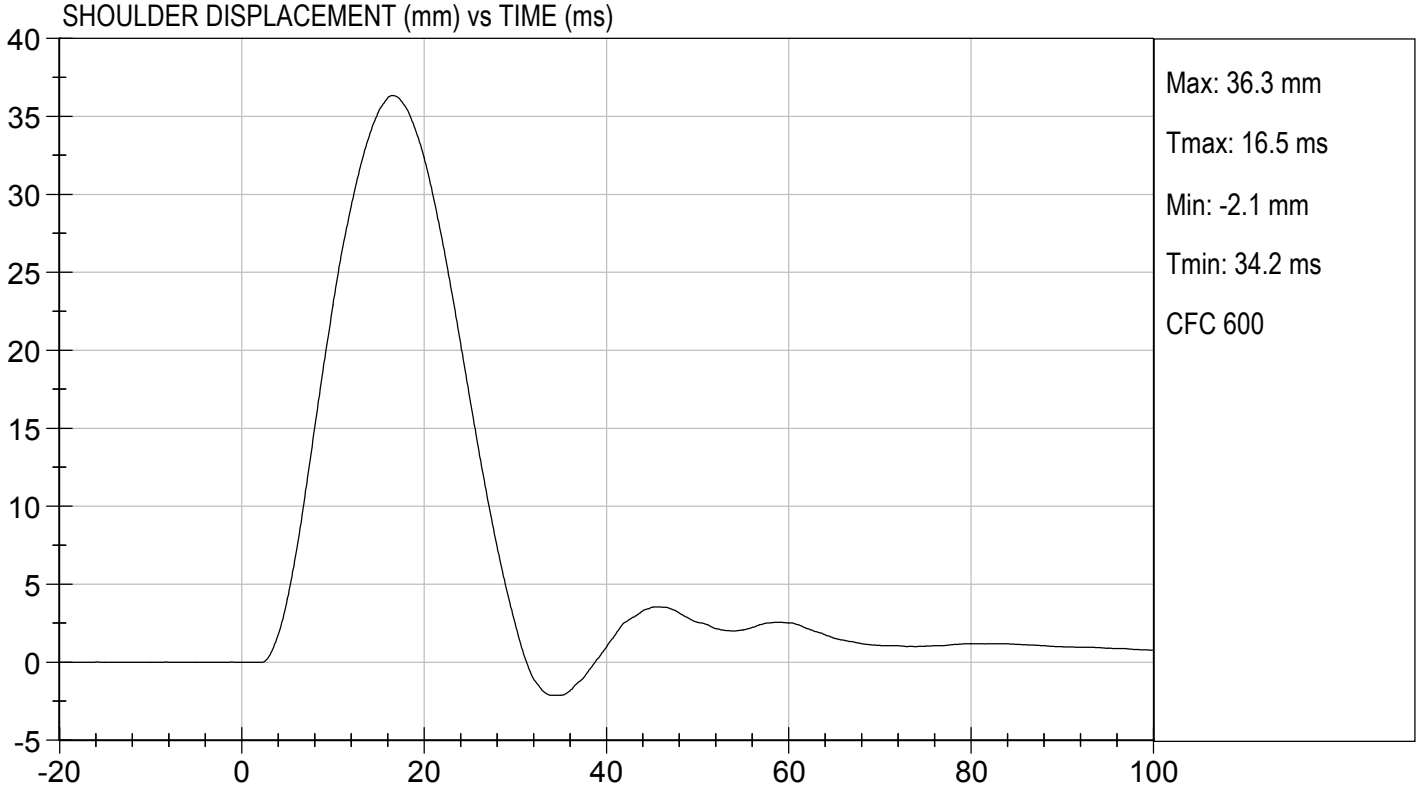
TEST DESC: THORAX IMPACT WITH ARM
VELOCITY: 21.65 ft/s, 6.60 m/s

TEST DATE: 10/04/2018
TEST #: D182964

PROBE (G's) vs TIME (ms)



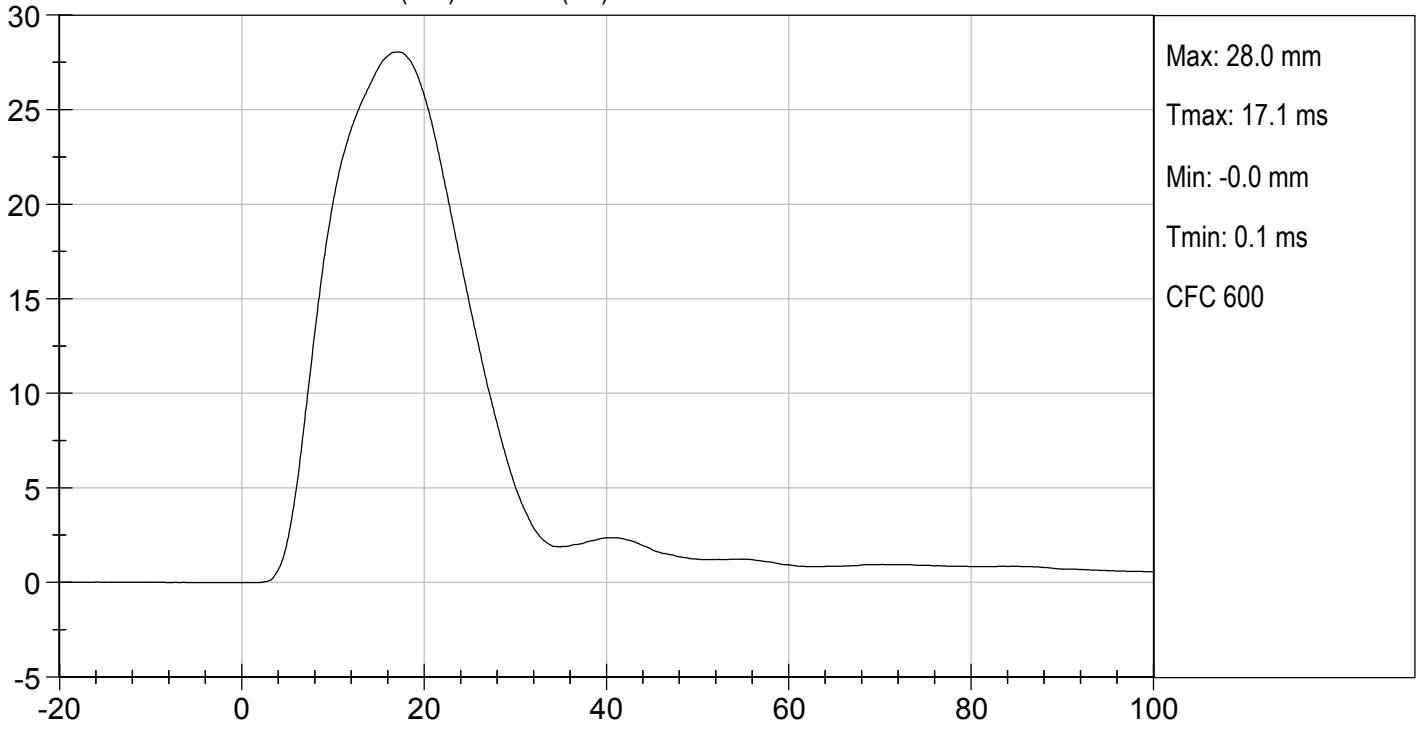
SHOULDER DISPLACEMENT (mm) vs TIME (ms)



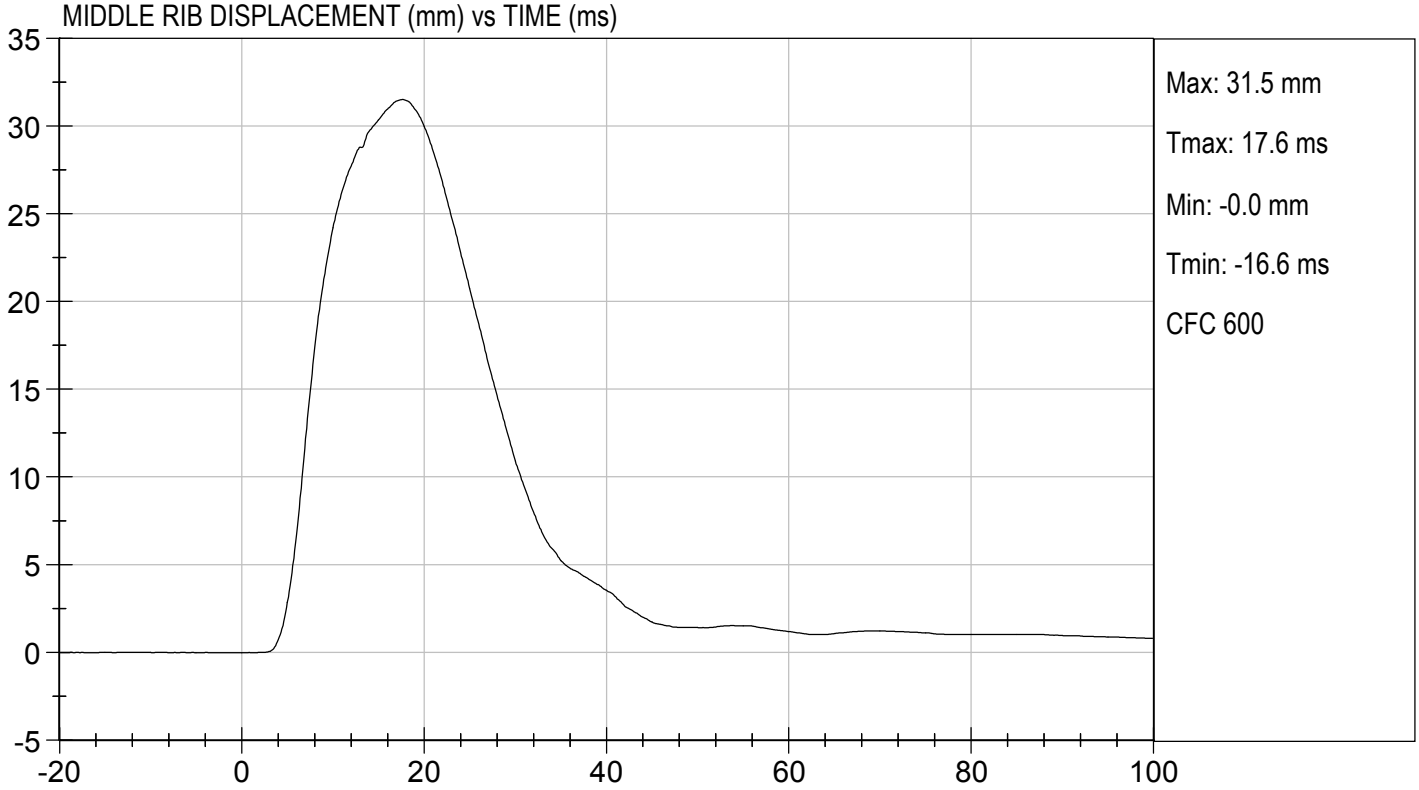
TEST DESC: THORAX IMPACT WITH ARM
VELOCITY: 21.65 ft/s, 6.60 m/s

TEST DATE: 10/04/2018
TEST #: D182964

UPPER RIB DISPLACEMENT (mm) vs TIME (ms)



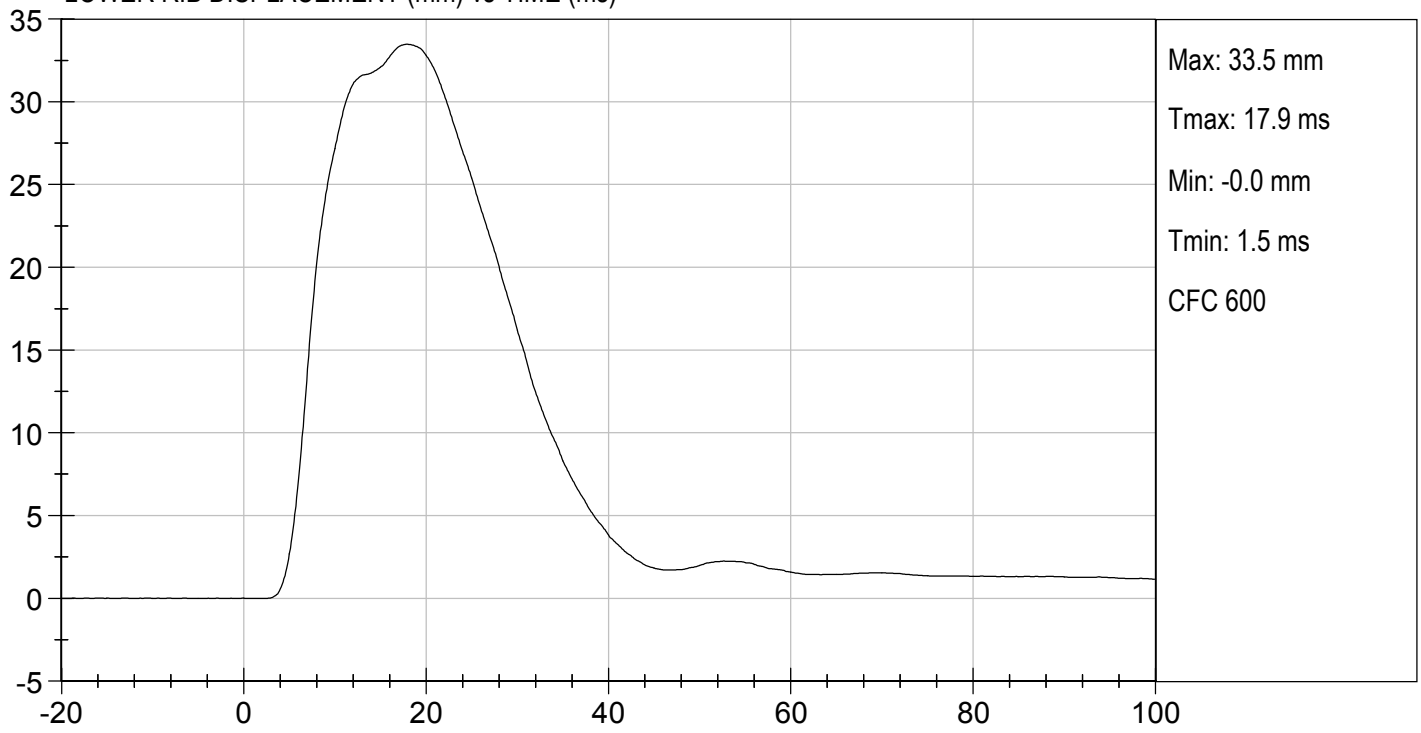
MIDDLE RIB DISPLACEMENT (mm) vs TIME (ms)



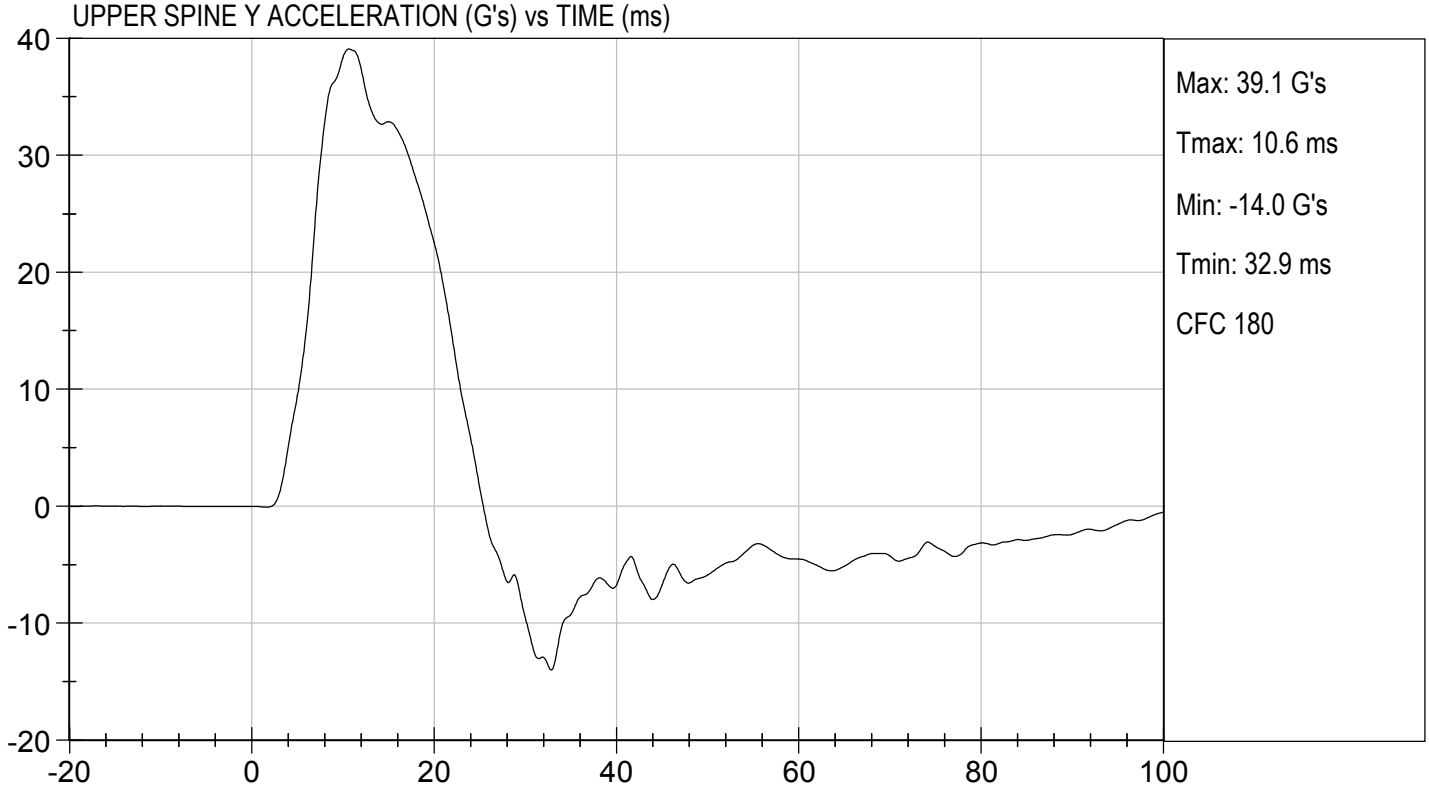
TEST DESC: THORAX IMPACT WITH ARM
VELOCITY: 21.65 ft/s, 6.60 m/s

TEST DATE: 10/04/2018
TEST #: D182964

LOWER RIB DISPLACEMENT (mm) vs TIME (ms)

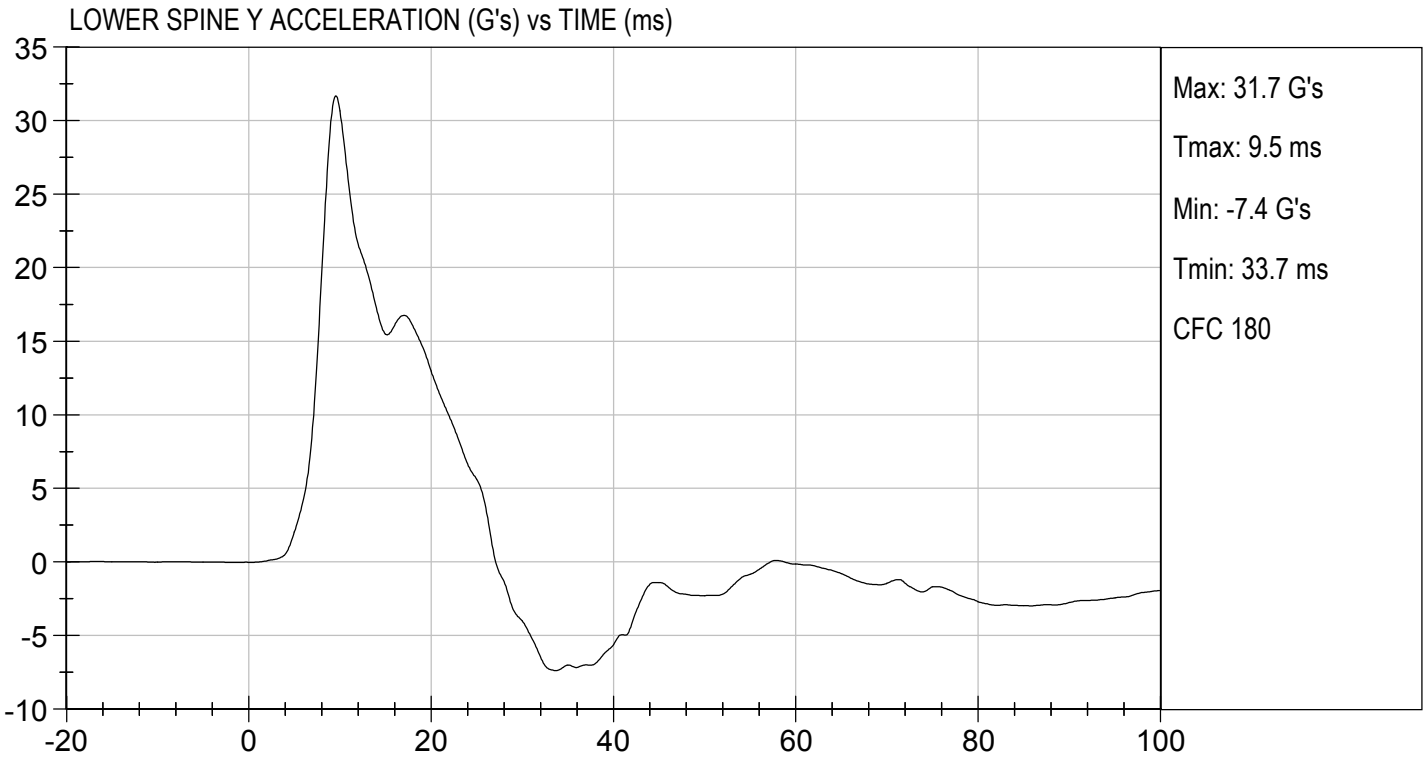


UPPER SPINE Y ACCELERATION (G's) vs TIME (ms)



TEST DESC: THORAX IMPACT WITH ARM
VELOCITY: 21.65 ft/s, 6.60 m/s

TEST DATE: 10/04/2018
TEST #: D182964



MGA RESEARCH CORPORATION

THORAX (WITHOUT ARM) IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182965

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.3	Pass
Humidity	%	10 to 70	39	Pass
Impact Velocity	m/s	4.20 to 4.40	4.27	Pass
Maximum Probe Acceleration	G's	14 to 18	15	Pass
Upper Rib Displacement	mm	32 to 40	38	Pass
Middle Rib Displacement	mm	39 to 45	41	Pass
Lower Rib Displacement	mm	35 to 43	35	Pass
Upper Spine (T1) Y Acceleration	G's	13 to 17	15	Pass
Lower Spine (T12) Y Acceleration	G's	7 to 11	8	Pass
		Overall Test Results		Pass

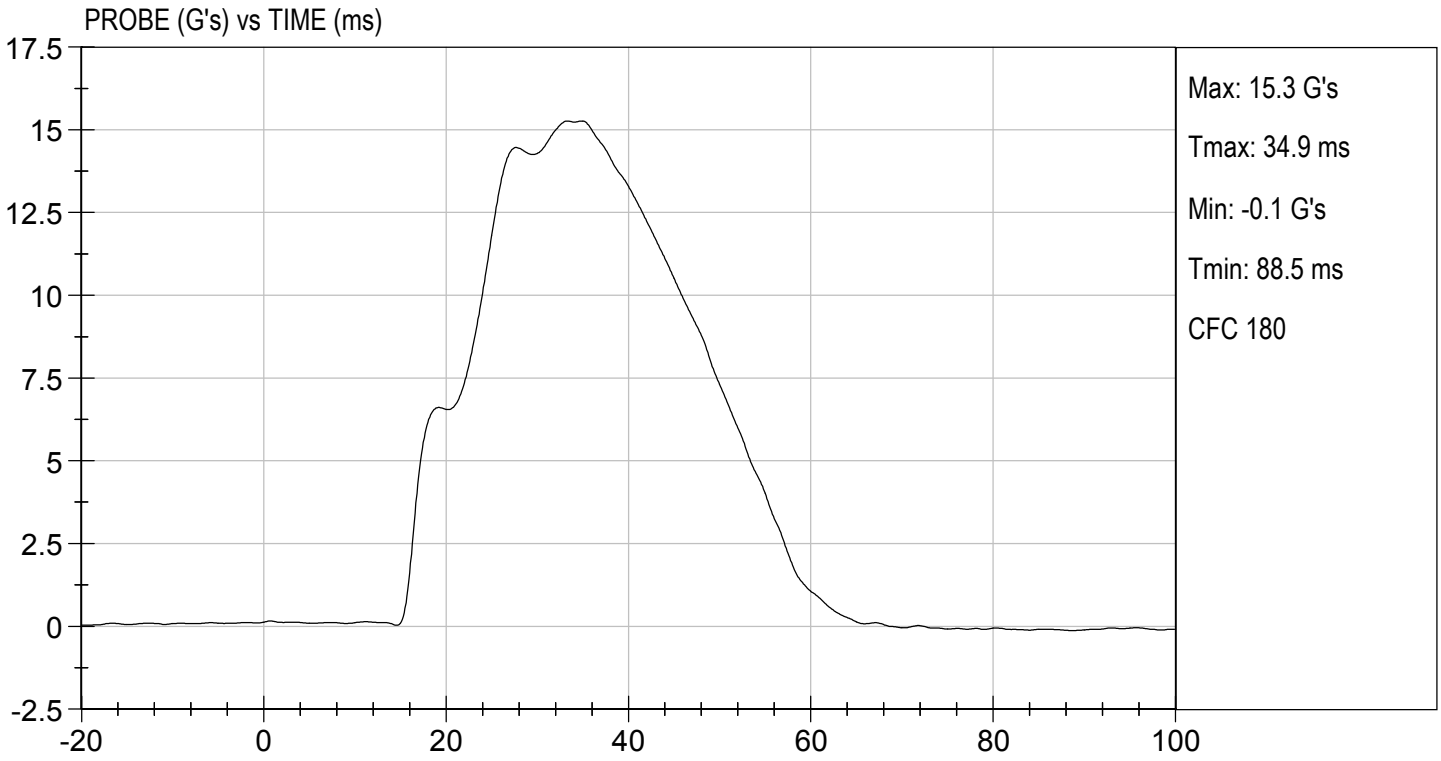
Jacob D Taylor
Laboratory Technician

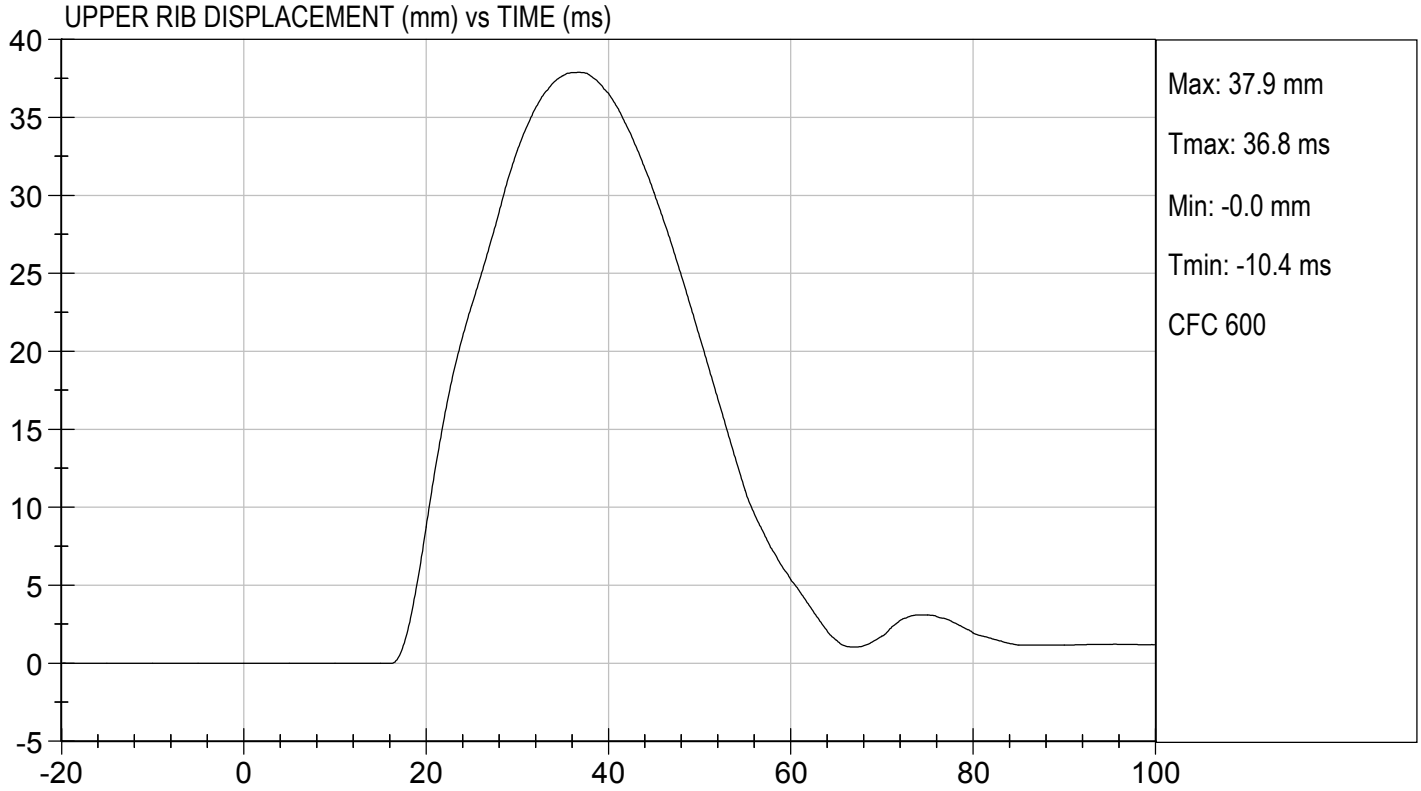
10/04/2018
Test Date

Approved By

TEST DESC: THORAX IMPACT WITHOUT ARM
VELOCITY: 14.01 ft/s, 4.27 m/s

TEST DATE: 10/04/2018
TEST #: D182965

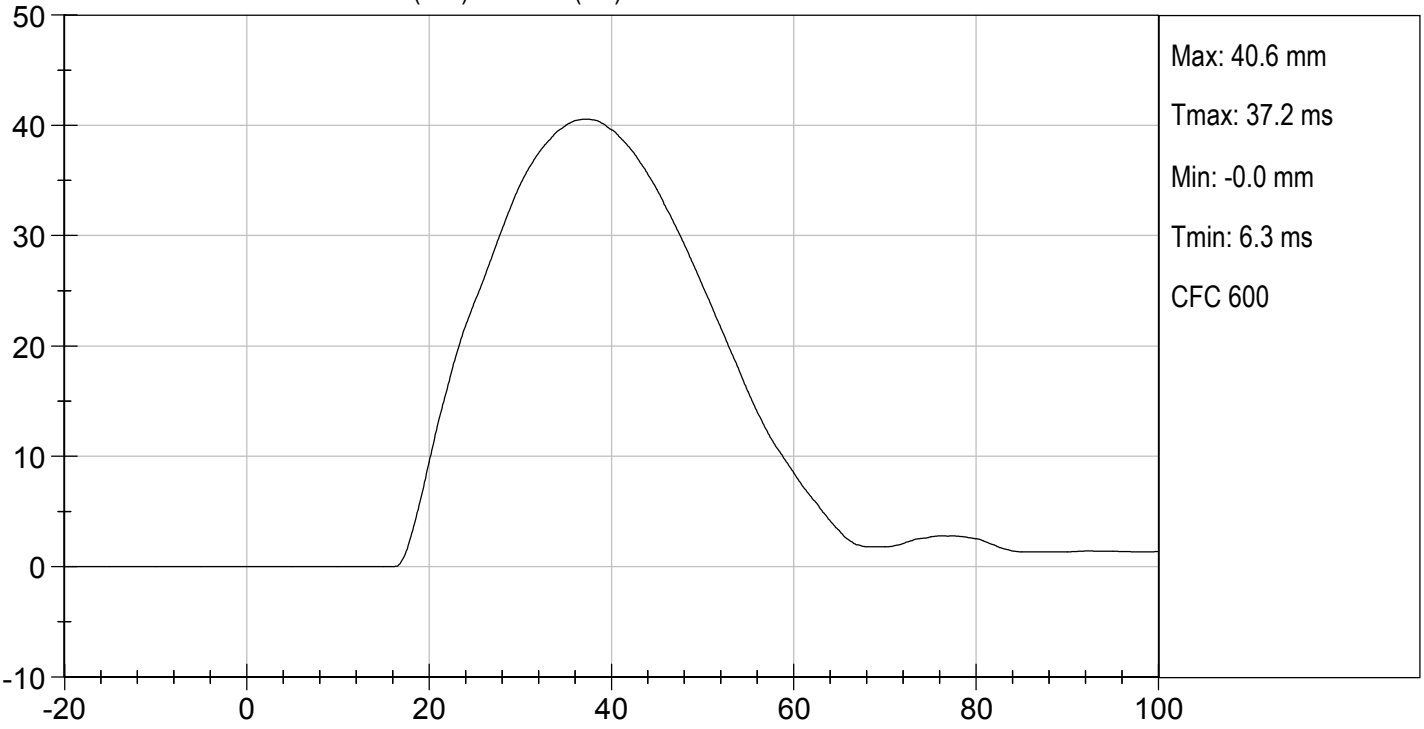




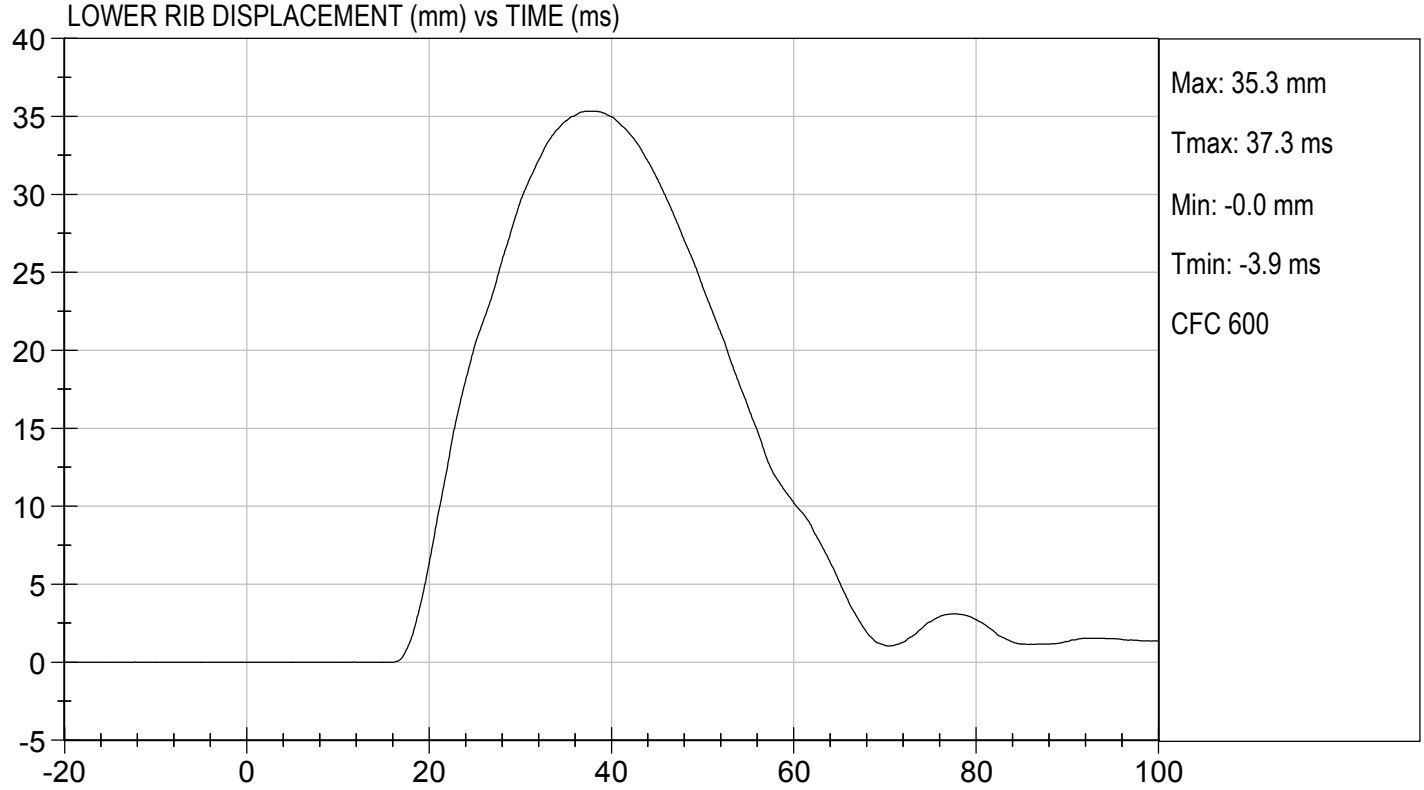
TEST DESC: THORAX IMPACT WITHOUT ARM
VELOCITY: 14.01 ft/s, 4.27 m/s

TEST DATE: 10/04/2018
TEST #: D182965

MIDDLE RIB DISPLACEMENT (mm) vs TIME (ms)



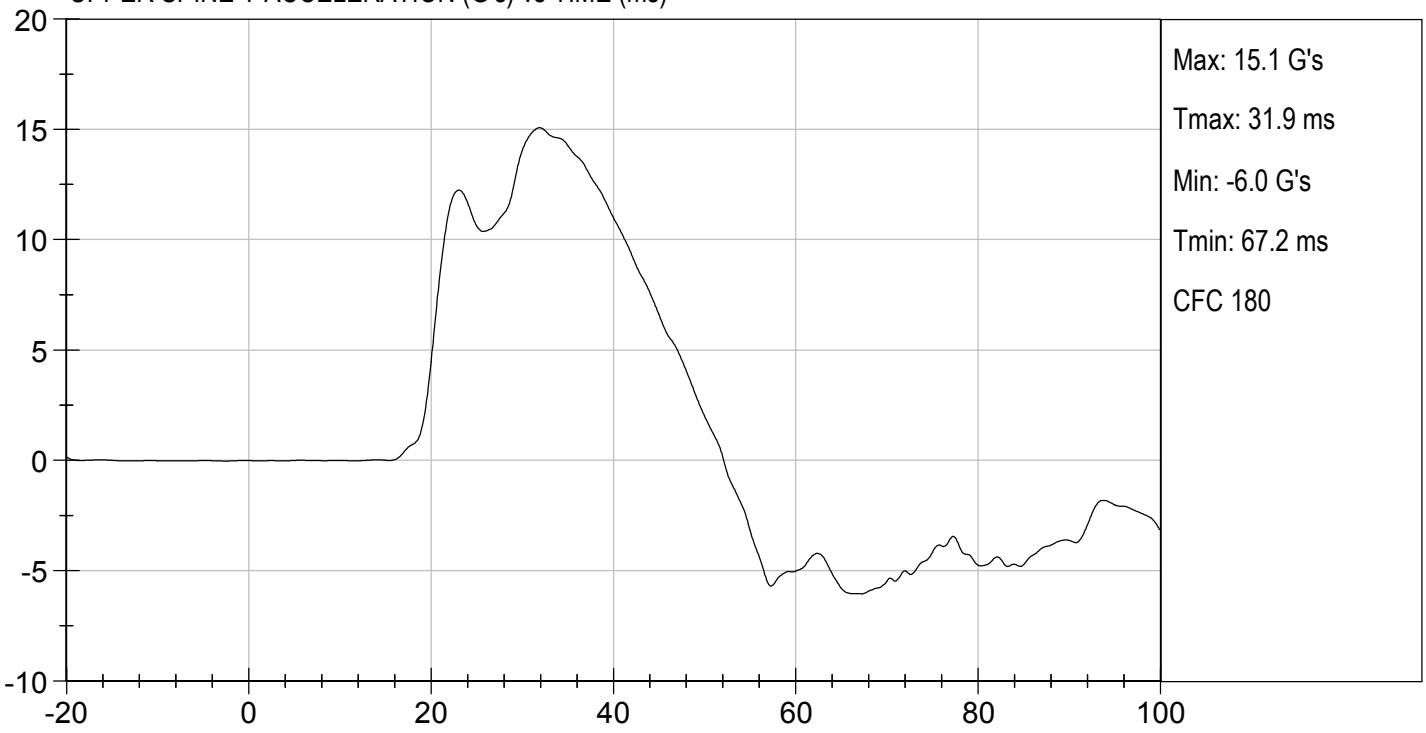
LOWER RIB DISPLACEMENT (mm) vs TIME (ms)



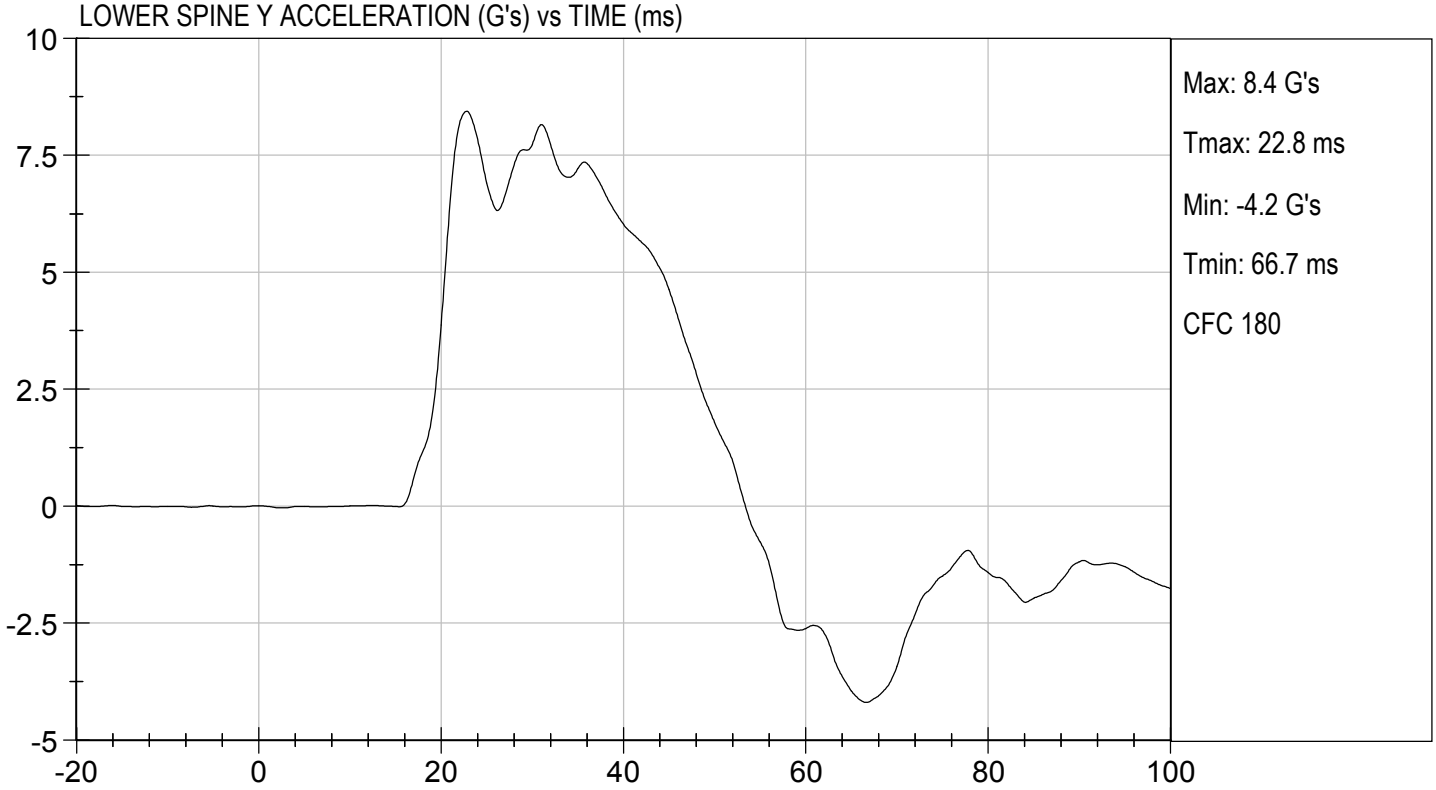
TEST DESC: THORAX IMPACT WITHOUT ARM
VELOCITY: 14.01 ft/s, 4.27 m/s

TEST DATE: 10/04/2018
TEST #: D182965

UPPER SPINE Y ACCELERATION (G's) vs TIME (ms)



LOWER SPINE Y ACCELERATION (G's) vs TIME (ms)



MGA RESEARCH CORPORATION

ABDOMINAL IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182966

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.3	Pass
Humidity	%	10 to 70	39	Pass
Impact Velocity	m/s	4.20 to 4.40	4.23	Pass
Maximum Probe Acceleration	G's	12 to 16	14	Pass
Upper Abdomen Rib Displacement	mm	36 to 47	41	Pass
Lower Abdomen Rib Displacement	mm	33 to 44	34	Pass
Lower Spine (T12) Y Acceleration	G's	9 to 14	11	Pass
		Overall Test Results		Pass

Jacob D Taylor

Laboratory Technician

10/04/2018

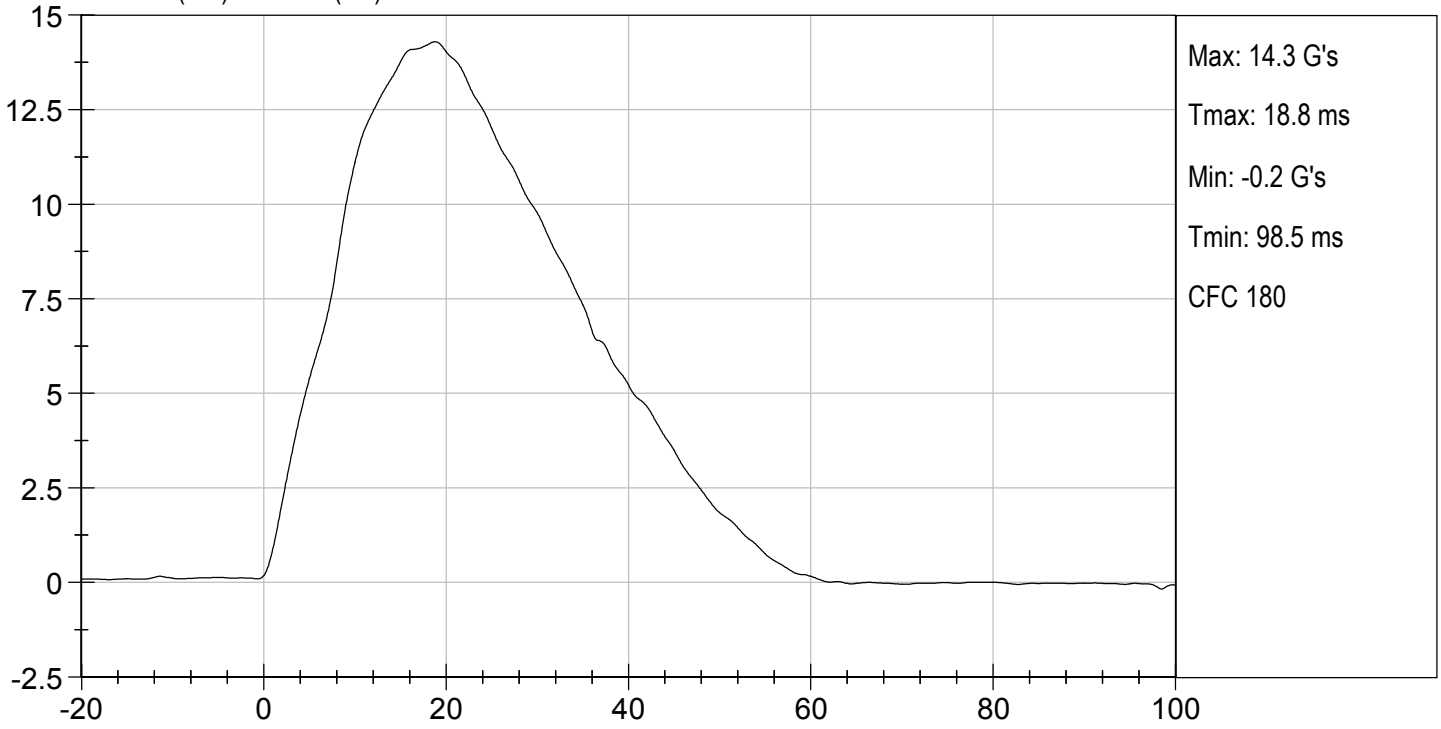
Test Date

Approved By

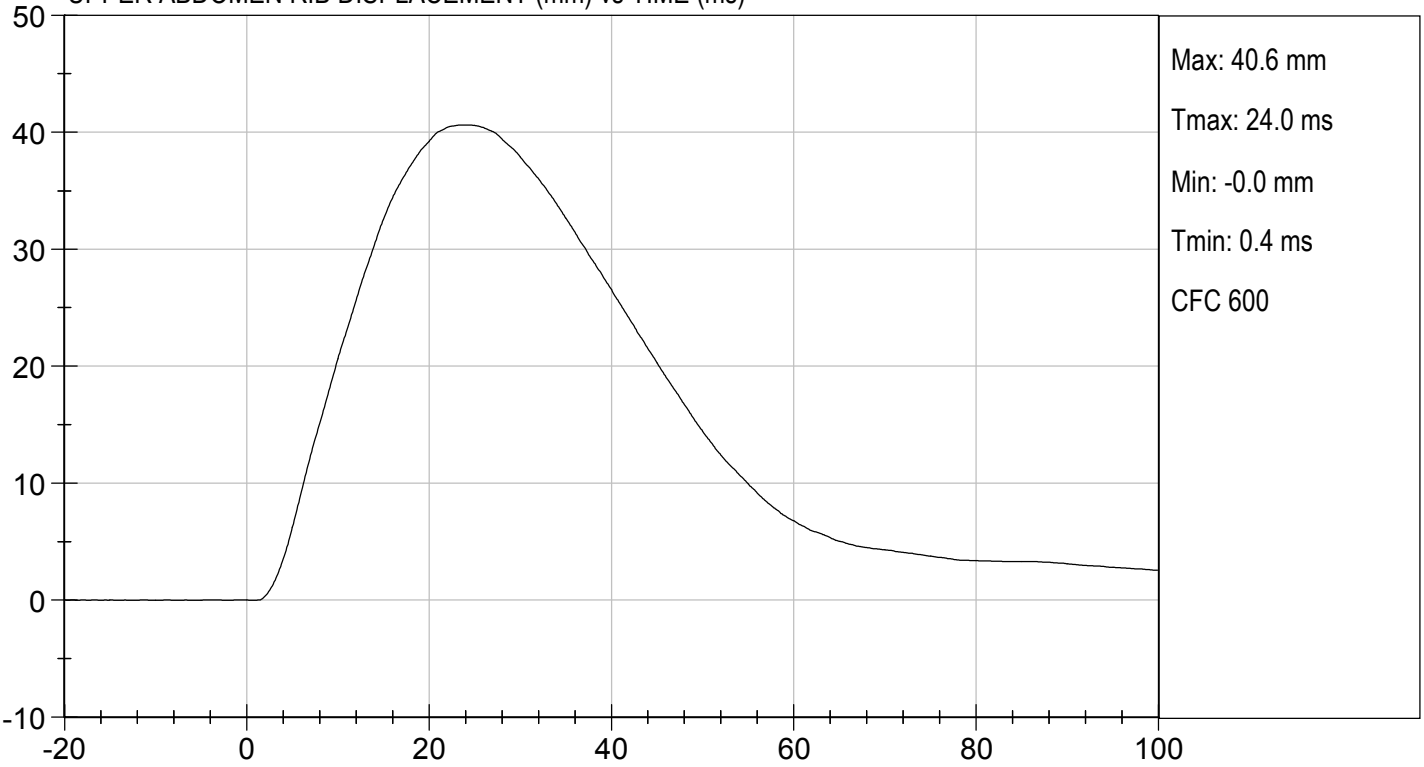
TEST DESC: ABDOMEN IMPACT
VELOCITY: 13.89 ft/s, 4.23 m/s

TEST DATE: 10/04/2018
TEST #: D182966

PROBE (G's) vs TIME (ms)



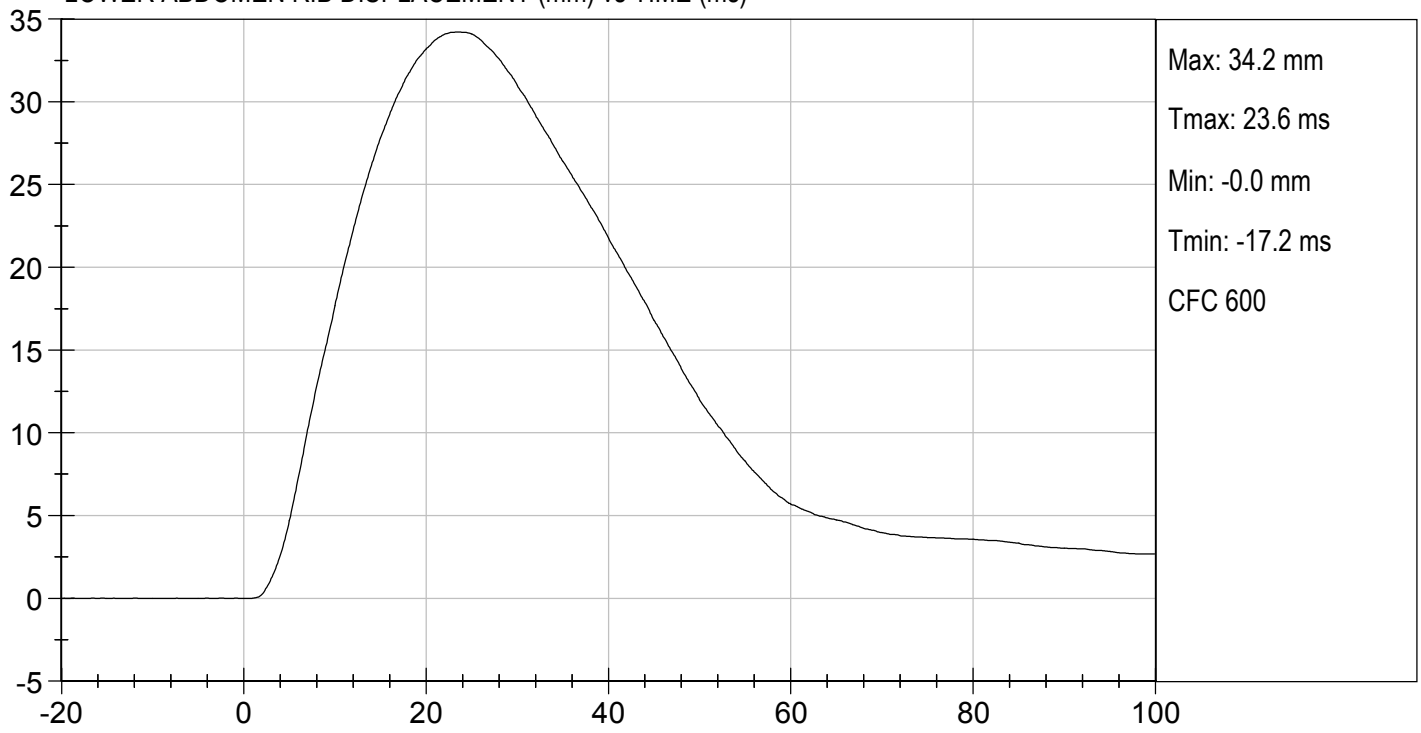
UPPER ABDOMEN RIB DISPLACEMENT (mm) vs TIME (ms)



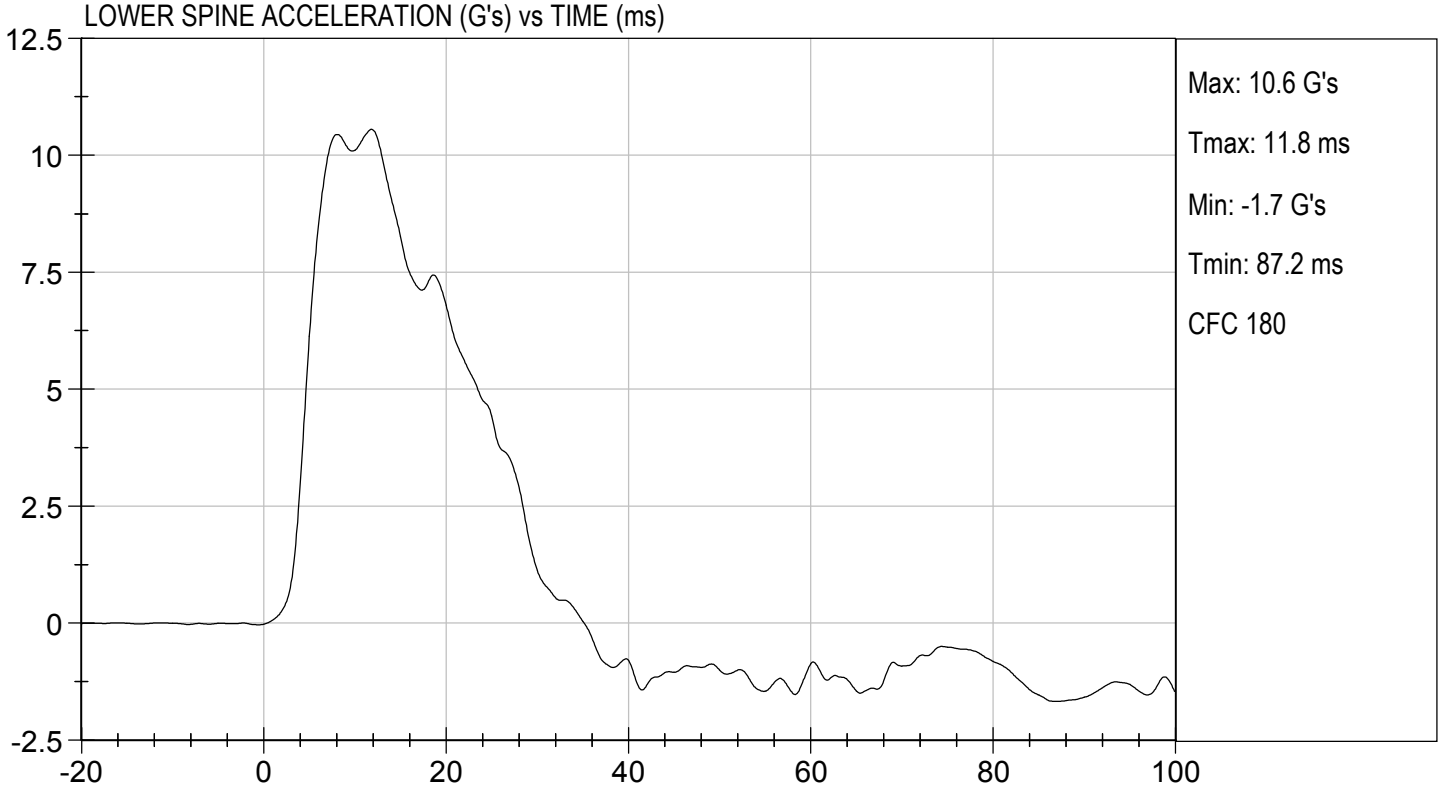
TEST DESC: ABDOMEN IMPACT
VELOCITY: 13.89 ft/s, 4.23 m/s

TEST DATE: 10/04/2018
TEST #: D182966

LOWER ABDOMEN RIB DISPLACEMENT (mm) vs TIME (ms)



LOWER SPINE ACCELERATION (G's) vs TIME (ms)



MGA RESEARCH CORPORATION

PELVIS IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182967

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.3	Pass
Humidity	%	10 to 70	39	Pass
Impact Velocity	m/s	6.60 to 6.80	6.61	Pass
Maximum Probe Acceleration	G's	38 to 47	46	Pass
Pelvis Y Acceleration After 6 ms	G's	34 to 42	41	Pass
Peak Acetabulum Force	N	3600 to 4300	4,037	Pass
		Overall Test Results		Pass

Danielle Redinbaugh
Laboratory Technician

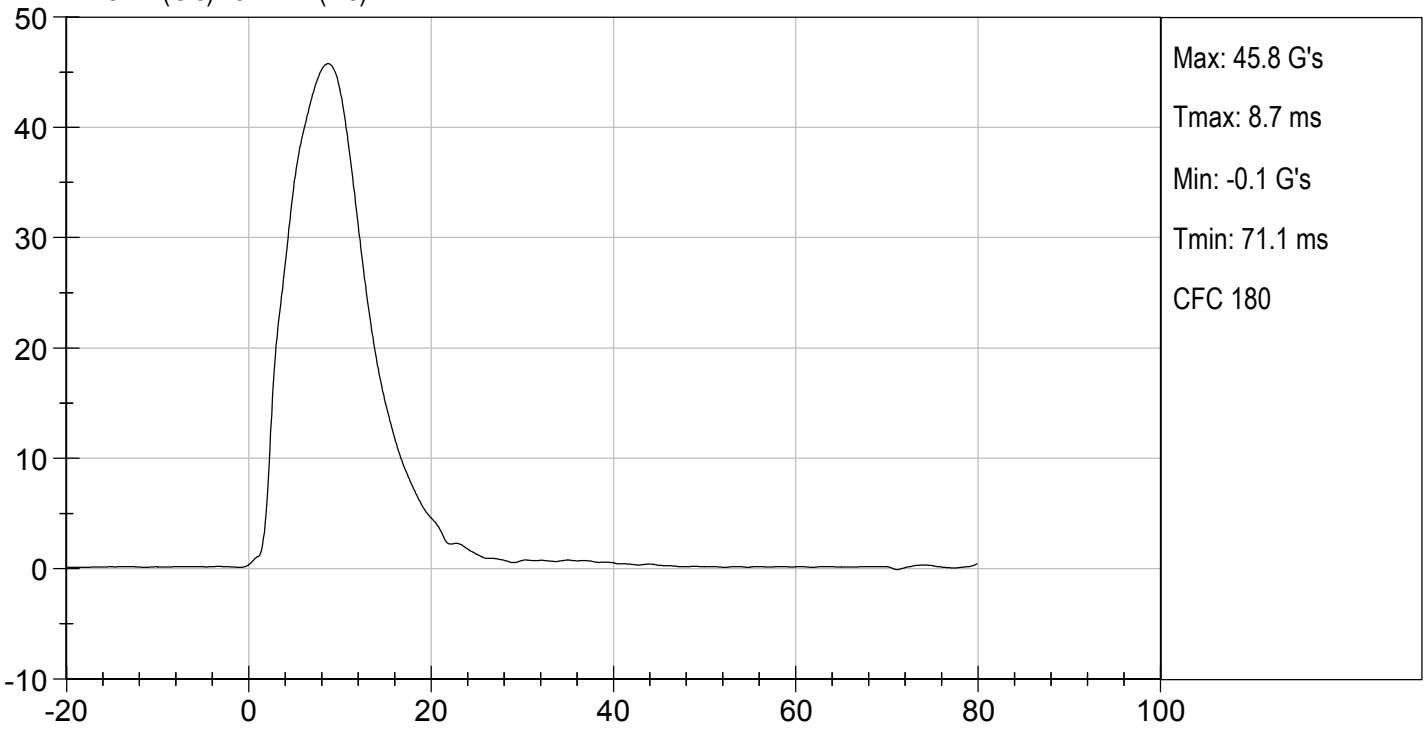
10/04/2018
Test Date

Approved By

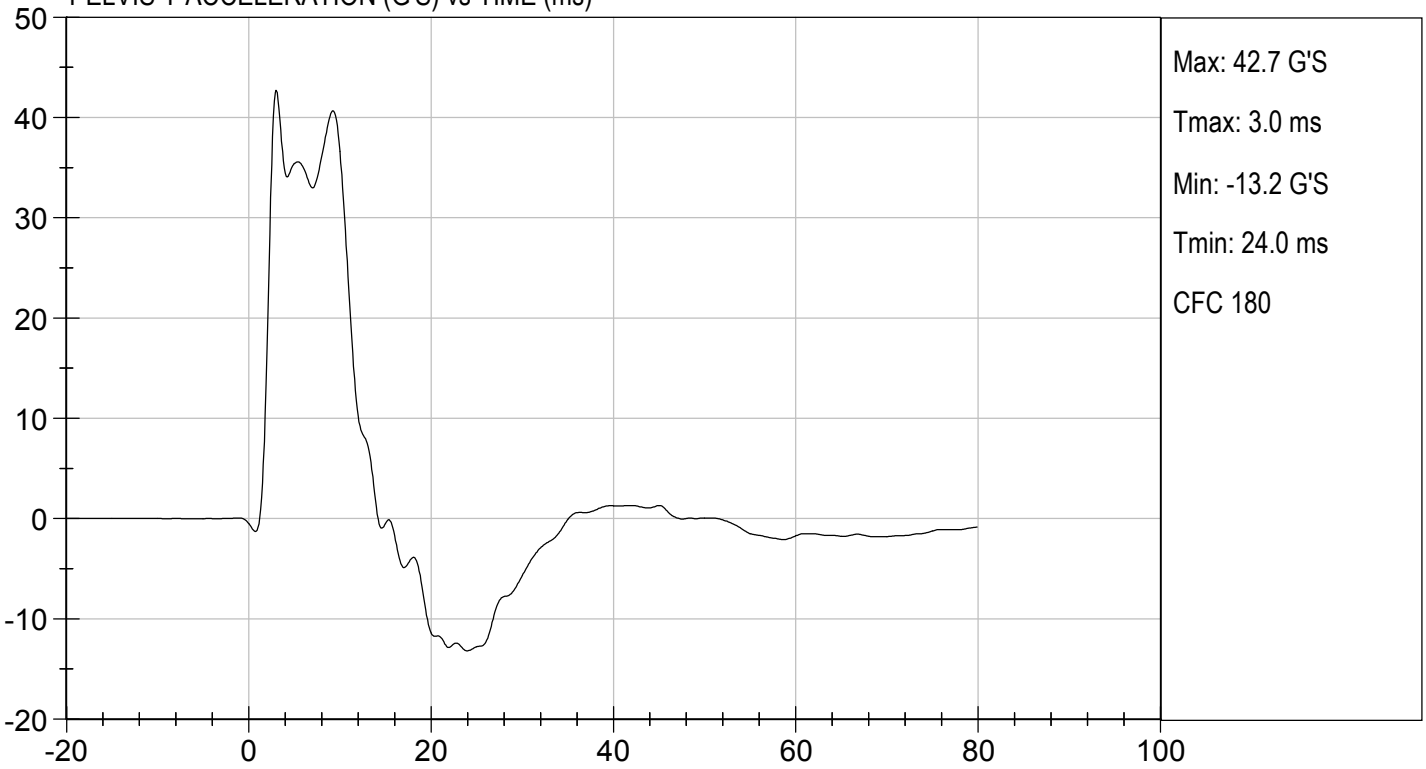
TEST DESC: PELVIS IMPACT
VELOCITY: 21.70 ft/s, 6.61 m/s

TEST DATE: 10/04/2018
TEST #: D182967

PROBE (G's) vs TIME (ms)

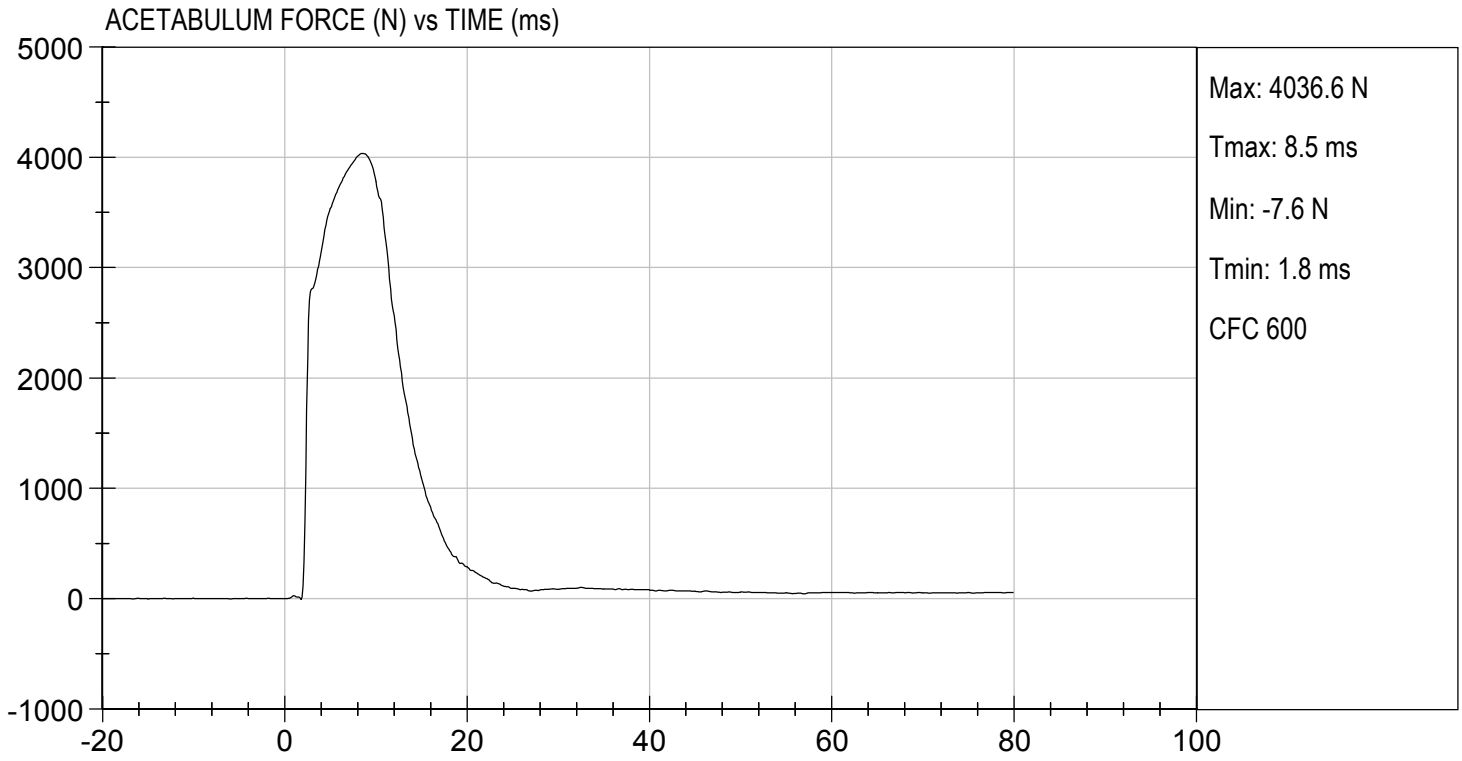


PELVIS Y ACCELERATION (G'S) vs TIME (ms)



TEST DESC: PELVIS IMPACT
VELOCITY: 21.70 ft/s, 6.61 m/s

TEST DATE: 10/04/2018
TEST #: D182967



MGA RESEARCH CORPORATION

ILIAC IMPACT TEST

SID-IIs BUILD LEVEL D DUMMY

ATD Serial No: 304 **Test I.D:** D182968

Tested Parameter	Units	Specification	Result	Pass/Fail
Temperature	deg C	20.6 to 22.2	21.2	Pass
Humidity	%	10 to 70	48	Pass
Impact Velocity	m/s	4.20 to 4.40	4.38	Pass
Maximum Probe Acceleration	G's	36 to 45	42	Pass
Pelvis Y Acceleration	G's	28 to 39	31	Pass
Peak Pelvis Iliac Force	N	4100 to 5100	4,862	Pass
		Overall Test Results		Pass

Danielle Redenbaugh
Laboratory Technician

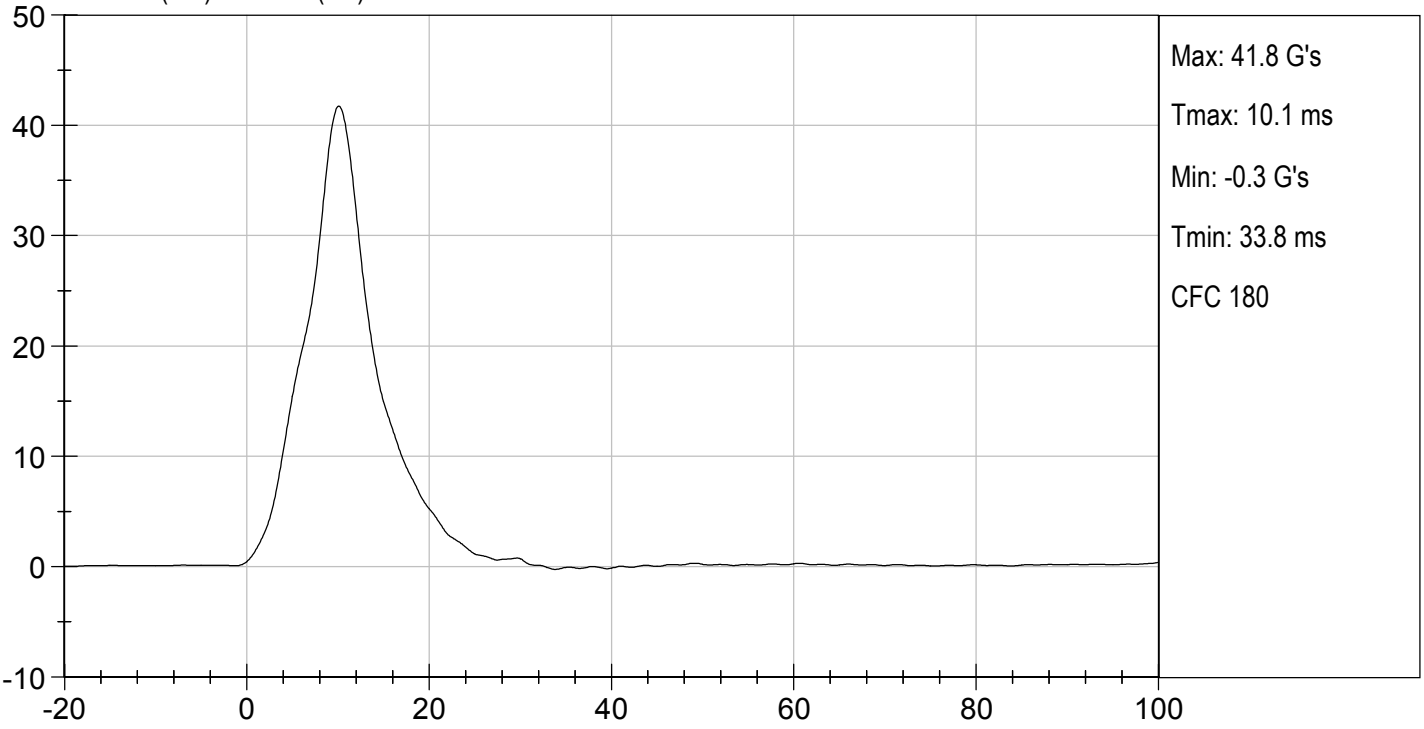
10/03/2018
Test Date

Approved By

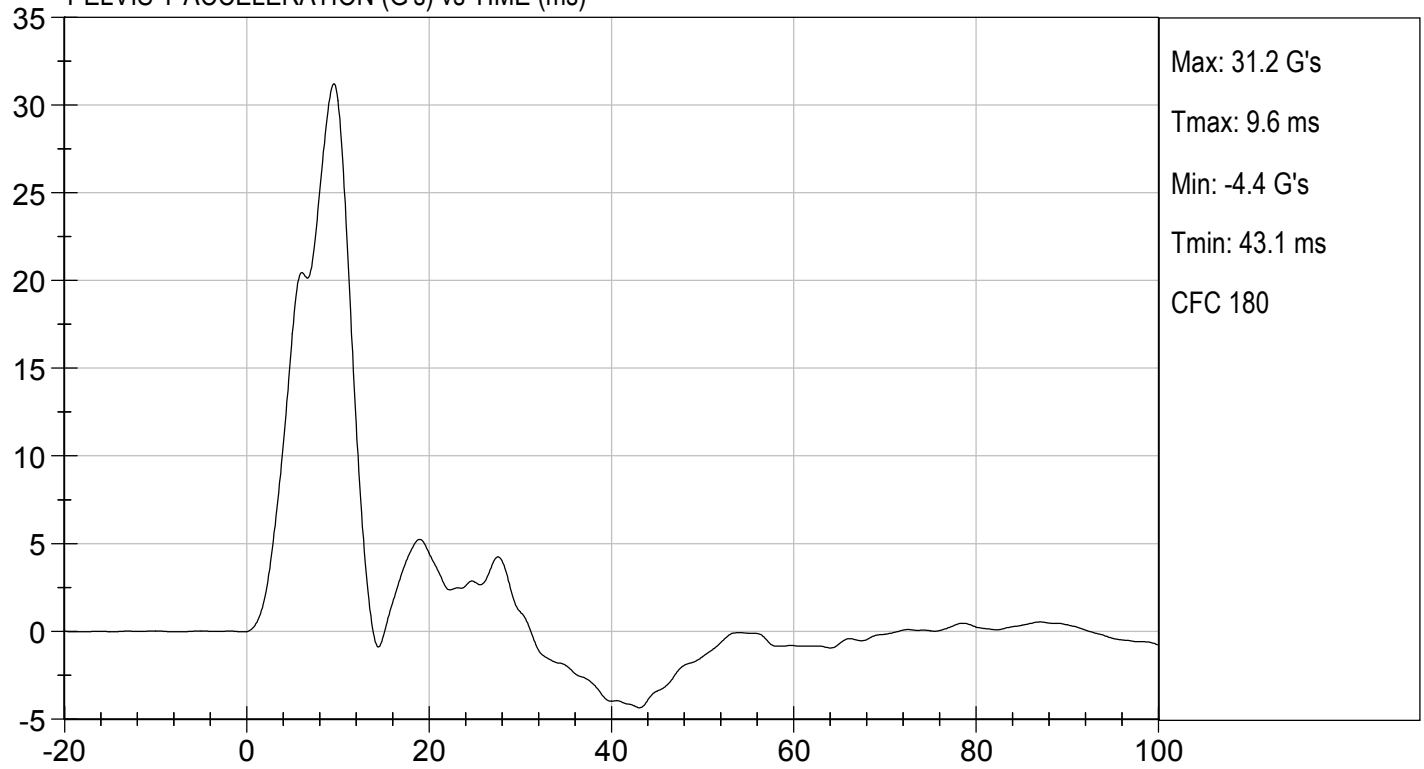
TEST DESC: ILLIAC
VELOCITY: 14.37 ft/s, 4.38 m/s

TEST DATE: 10/03/2018
TEST #: D182968

PROBE (G's) vs TIME (ms)

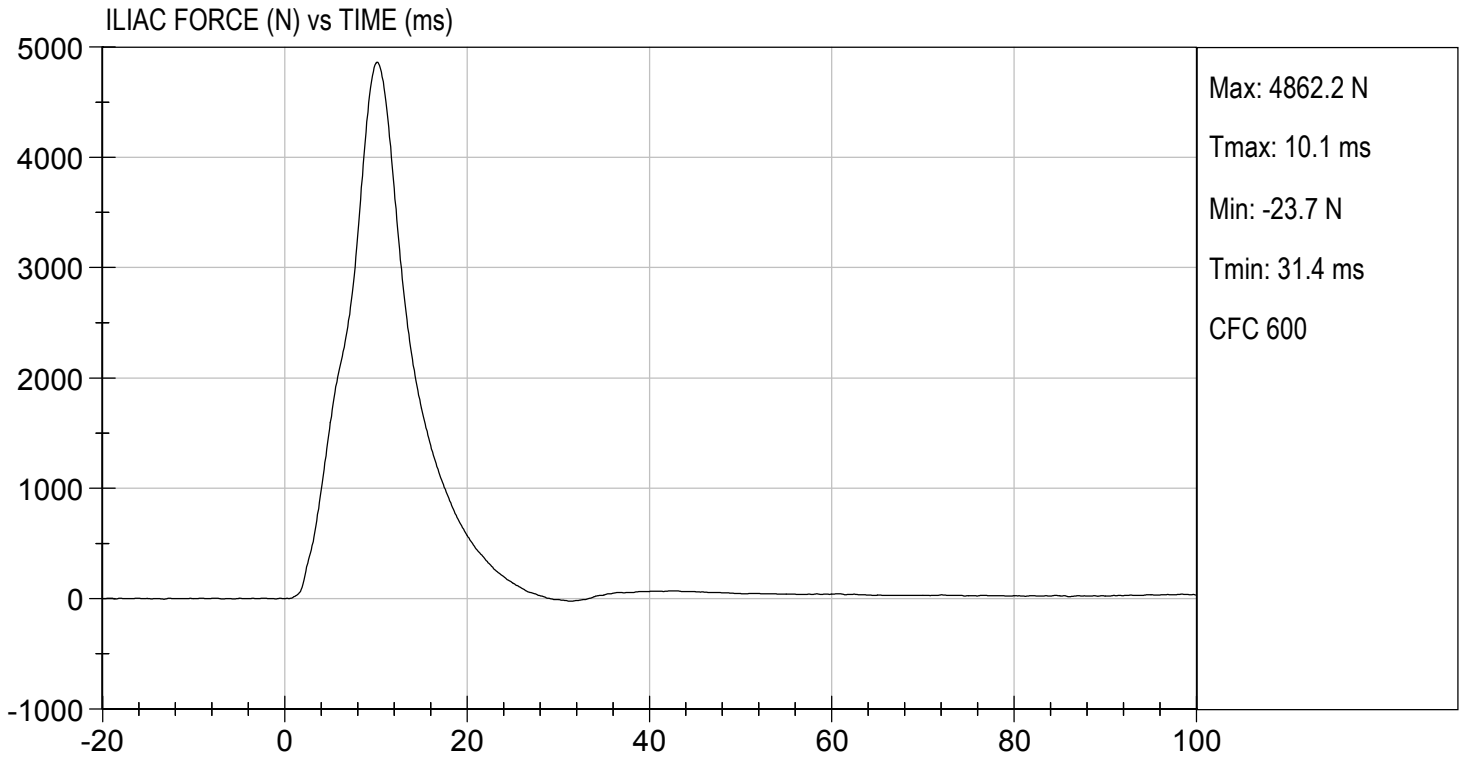


PELVIS Y ACCELERATION (G's) vs TIME (ms)



TEST DESC: ILLIAC
VELOCITY: 14.37 ft/s, 4.38 m/s

TEST DATE: 10/03/2018
TEST #: D182968



APPENDIX D
TEST EQUIPMENT AND INSTRUMENTATION CALIBRATION DATA

Table 1 – Dummy Instrumentation

		SID-IIs S/N 304		
		Serial Number	Manufacturer	Calibration Date
Head CG Accelerometers	X	P83047	Endevco	08/08/18
	Y	P83048	Endevco	08/08/18
	Z	P83049	Endevco	08/08/18
Upper Neck Load Cell		NG1911	Denton	08/24/18
Lower Neck Load Cell		LNG149	Denton	08/24/18